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MODERN TRENDS IN AIR TRANSPORT

W. F. DURAND

In a domain as varied and as active as is air transport at the present time, I can only hope, in the time which I must occupy this evening, to touch on some of the more important phases of the subject. And first, by way of introduction, I should like to rehearse with you a few simple and elementary points regarding the airplane—a body heavier than the air, yet which, for service in air transport, must depend on sustained movement through the air.

Let us then picture the airplane as a complex of four systems as follows:

1. The lifting system.
2. The non-lifting system.
3. The propulsive system.
4. The control system.

The lifting system is, of course, represented by the wings. The non-lifting system is represented by the body or fuselage, the purpose of which is to provide a central member for the entire structure with space for personnel and pay load, to provide suitable support and location for the rudder and elevator as parts of the control system, and often to house, at the nose, an engine and propeller shaft. The propulsive system comprises the engines and propellers with function, of course, as indicated by the name. The control system comprises rudders, elevators, ailerons, flaps, slots, etc., all intended to place in the hands of the pilot the movement of the plane in the air and also in taking off from the ground and returning thereto.

Now what are the things about an airplane and its performance in which we have a special interest? I shall put them down in this order:

Safety.
Carrying capacity.
Speed.
Range.
Economy.
Comfort.

This may or may not be the order of relative importance, according to the viewpoint from which "importance" is judged. Thus the order of importance for planes in commercial service and in military or naval service would be, in general, not the same. It will, moreover, be convenient to discuss the present trend with

regard to these various characteristics in a somewhat different order and I shall take first No. 2, carrying capacity.

The laws of fluid mechanics tell us immediately that the lift of an airplane wing increases directly with the area, with the square of the speed and, over most of the practical working range, with the angle of attack of the air on the face of the wing. This angle may, for our present purposes, be represented by the angle between the direction of motion of the plane and a fore and aft line touching the under face of the wing. It represents what may be called the attitude of the wing relative to its direction of motion.

It would appear then, that in order to increase the lift of an airplane wing, we have only to select some combination of larger area, higher speed and greater angle of attack. It is not, however, quite so simple. What we are ultimately concerned with is not so much the *gross* lift of the plane as the useful part of this lift—that is, the balance of the total lift over and above what is necessary to sustain the weight of the plane, including engines and propellers. In thus approaching the economics of airplane operation, we recognize two major subdivisions of the total lift.

1. The weight of the plane, including power plant (engines and propellers).
2. The useful load subdivided into:
   a. Fuel and oil, operating personnel, supplies.
   b. Pay load—passengers, mail, express matter, etc.

Again, the weight of the plane together with its power plant may be viewed as a dead load which must be sustained in the air simply in order to realize the purposes of flight; while the useful load represents the part of the total lift disposable as may be desired between fuel, supplies and personnel on the one hand, and pay load on the other. Thus with a small fuel load, a relatively large pay load may be carried for a short distance; with a large fuel load, a relatively small pay load may be carried for a long distance.

Now to return to the results following an increase in wing area—or in general an increase in the size of the plane. As we have seen, other things being equal, the lift will increase with the area. But the weight of the structure will increase likewise, and the results on the useful load are, therefore, by no means assured. In order to follow this point more closely, we must now discriminate between the weight of the plane simply as a structure and the weight of the power plant which it houses. I have referred to the sum of these two weights as the weight of the plane in contradistinction to the amount of useful load which it can carry. We may now refer to the aggregate weight of the structural elements of the plane simply as the weight of the structure. With these conventions, then, weight of plane equals weight of structure plus weight of power plant, and the total lift must equal weight of the structure plus weight of power plant plus the useful load.

Let us now turn to the relation between weight of structure and wing area. We have seen that gross lift, other things being equal, will increase with the area—that is with the square of a linear dimension. Now it is an inescapable consequence of the laws of structural mechanics that, for structures under bend-

ing stress, carrying the same load per unit of area, and with the same geometry of design and materials of construction, the dimensions of all structural elements must vary in the same ratio as that for the overall dimensions. This means, for example, that if the overall dimensions were increased two-fold, the wing area would be increased four-fold, while the volume and hence the weight of all structural elements would be increased eight-fold. This is often referred to as the square-cube law implying, as it does, that with increase in overall dimensions, the lift will increase with the square of the linear dimension and the weight of the structure with the cube. According to this law, then, with increase in size, the weight will increase at a much faster rate than the lift, and, unless some escape is found, this excess weight would soon absorb the difference between the total lift and the weight of the plane and thus reduce the useful load to zero. The law is inexorable under the conditions stated, and in the early years of airplane development, led to prophecies of sharp limitation in the increase in size of airplane structures. The ways and means whereby the consequences of this law have been evaded form one of the most brilliant achievements in the development of airplane design and construction. I must take only the time to indicate some of them in briefest outline. They comprise first, more efficient methods of design whereby the material employed is more effectively distributed with reference to the loads to be carried; second, improved materials of construction; third, improved aerodynamic design whereby for the same power, increased speed may be obtained, and with increased speed, increased lift with the same wing area; fourth, distribution of load along the wing, as by way of fuel and engines, and the reduction thereby of the resulting bending moment on the wing structure.

There is a further factor which helps in the same direction. The structure of the plane, under certain conditions, as we have seen, would be subject to this square-cube law. The power plant would not be so subject. Power is related primarily to surface or, broadly, to wing area. For the same speed, therefore, the power required will increase with the wing area, or as the square of the linear dimension rather than as the cube. One part of the weight of the plane is, therefore, not subject to this law, even under the conditions where the weight of the structure would be. This helps to reduce the rate of increase of weight of plane with increase in size.

Another factor in increase of lift is higher speed and this has been used with telling effect since lift increases as the square of the speed. However, increased speed means larger engines and more weight of power plant, as well as more lift per unit of area and, therefore, more loading per square foot of wing area. The law of compensation holds here; if we would obtain more lift we must buy it at a price.

A third factor in increase of lift is increased angle of attack between the air and the wing. This is indeed effective, but it demands too heavy a price. With the increase of lift comes also an increase of drag or resistance to the motion of the plane. This means more engine and more power plant weight for the same speed, or a reduced speed for the same power plant weight. The price is too high and can only be afforded during periods of maneuver at low speed,

as in taking off from the ground, or landing thereon, where the decrease in lift due to decreased speed is compensated by the increase due to greater angle of attack. However, through a combination of better design, better materials, higher speed and other contributing factors, the consequences of this law have been thus far evaded and it would be a brave man who would now attempt to place a limit to future increase in size.

Twenty years ago, during the great war, there was no commercial aviation. The total lift, *i.e.*, the total loaded weight of military planes was, for the most part, from three to five thousand pounds. The earliest commercial transport planes had a total loaded weight from five to ten thousand pounds. The planes in current transport service weigh loaded 20,000 to 40,000 pounds; the *China Clipper* has a loaded weight of 52,000 pounds. The new *Boeing* flying boat will weigh loaded 82,000 pounds, the new *Douglas 4*, which has been undergoing test flights, will have a loaded weight of 65,000 pounds. Beyond these figures, new designs have been submitted by four builders for transatlantic service, the loaded weight of which will be about 200,000 pounds.

Some further particulars of these latest planes may be of interest. The present standard *Douglas 3* of 24,000 pounds total lift has a wing spread of 95 feet, a wing area of 985 square feet, a wing loading of 24.3—that is, each square foot of wing area supports in flight 24.3 pounds. It has engines developing 2,000 horsepower, a cruising speed of 170 miles per hour, a range of 500 miles with a pay load of 5,200 pounds including 21 passengers. Corresponding figures for the present *China Clippers* are: Weight 52,000 pounds, spread 130 feet, wing area 2,320 square feet, wing loading 22.5, power, four engines developing 3,600 horsepower, cruising speed 130 miles per hour, range 2,400 miles and pay load 2,600 pounds including eight passengers. The new *Douglas 4* of 65,000 pounds has wing area 2,130 square feet, wing spread 138 feet, wing loading 30.5, power, four engines developing 5,600 horsepower, cruising speed 170 miles per hour, range 1,000 miles with a pay load of 9,400 pounds including forty passengers. The new *Boeing* flying boat with a total lift of 82,500 pounds has wing area 2,880 square feet, wing spread 152 feet, wing loading 28.8 pounds, four engines developing 5,950 horsepower, cruising speed, 150 miles per hour, range 2,400 miles with a pay load of 10,000 pounds, including forty passengers.

The recent *Boeing 307,* intended especially for stratosphere flight, with a total lift of 42,000 pounds has a wing area of 1,390 square feet, a wing spread of 107 feet, wing loading 30.3 pounds, four engines developing 4,150 horsepower, cruising speed 175 miles per hour, range 1,000 miles with a pay load of 9,200 pounds, including thirty-three passengers.

Then passing to the future, the new design, referred to above, proposed for transatlantic flight with a total lift of 200,000 pounds, will have a wing area approximately of 4,450 square feet, a wing loading of 45 pounds, engines developing 11,750 horsepower, cruising speed 250 miles per hour, range 3,700 miles, with a pay load of 25,000 pounds including 100 passengers.

In these figures for horsepower and speed, it should be noted that the power is the maximum developed by the engines, used normally only when taking off. The cruising power usually varies from 50 to 60 percent of this. With full

power, the top speed would be some 25 or 30 percent higher than the cruising speed.

These illustrations are all of American design and manufacture. It must not be supposed, however, that we stand alone in this march of progress. England, France, Germany, Italy and Russia are all thinking and designing along these same general lines. I shall attempt no comparisons since my purpose tonight is simply to indicate the trend of progress, and for this purpose the American designs will serve as well, or perhaps better than those from abroad. I may, however, go so far as to say that no foreign design actually built appears to have the promise of the *Boeing* boat No. 314, and no designs, especially for trans-atlantic service, appear to be quite in the class with those submitted in competition for the contemplated 200,000-pound type, to which I have just referred.

In summarizing the characteristics of these modern airplanes, the wing loading was noted as one of the significant features. This, we remember, is the total lift or total weight divided by the wing area—that is, the lift per square foot of area. Perhaps no characteristic of an airplane shows more clearly the advance during the quarter century than does this figure. Twenty or twenty-five years ago each square foot of wing area was expected to lift some 8 or 10, perhaps 12 pounds. But with improved form and increased speed, these figures have been raised to 30 and 40 and above in recent designs. It may be of interest to note that for flying birds, this ratio is of the order of 2 to 4. This is due, in part at least, to the lower speed at which the bird flies, especially as compared with the modern trend in airplane speeds.

This brings us to the question of speed. A quarter of a century ago, airplane speeds were of the order of 50 to 80 miles per hour, and airplanes were chiefly for military or naval use. Today, cruising speeds of 150 to 200 miles per hour are the accepted normal, with top speeds considerably higher. What then is the outlook for the future? Is there a limit to the speed of the airplane? Here again, no one can safely predict. Suppose, however, we put the question a little differently, in this way. Assuming available the present content of the domains of science, engineering and technology, with everything sacrificed to the one feature of speed, and supposing all of the factors affecting speed combined in the optimum manner and degree; what speed might we then expect? With the question put in this manner, it is possible to give, at least, an approximate answer and it works out to be somewhere about 500 or 550 miles per hour. How closely has this figure been approached? What is the present speed record? Here the answer is 424 miles per hour held by an Italian seaplane. It should be noted, however, that such a plane has no commercial value. Everything has been sacrificed to speed. Almost the entire useful load has been given over to engine weight, leaving only a small margin for a few gallons of fuel and the pilot. The course is two kilometers or about a mile and a quarter. And thus, by a *tour de force,* as we may term it, with everything made subservient to this special purpose, this speed of 424 miles per hour has been attained, and speeds closely approaching 500 miles per hour appear to be quite within the framework of possible modern achievement—if we are willing to pay the price.

At the same time we should perhaps remember that outside the possibilities of commercial stratosphere flight—and which are yet unproven— it does not appear probable, in any near future and with the present content of science, engineering and technology, that we shall much exceed service speeds of 300 miles per hour for commercial planes and perhaps 350 or 400 miles per hour for the fastest military or naval fighting planes. In planes for actual service, the margin between total lift and the weight of the structure cannot be almost entirely given over to power plant. Some sensible part of the total lift must be allotted to fuel and to pay or fighting load and this means reduced power plant capacity as compared with the plane where a short burst of speed is the sole object.

Let us now turn to another item of airplane performance—range, by which is meant the distance flown without grounding or refueling. Here again the answer depends on the special conditions imposed; and in particular on the division of the useful load between fuel and pay load. If we go to the limit, with no pay load whatever, with all of the margin between the total lift and the weight of the plane devoted to fuel, consumable supplies and minimum crew, it again becomes possible to give an approximate answer to the maximum distance which can be flown. This distance works out to be from 8,000 to 9,000 miles; and this again, we must note, is a performance worked out within the framework of our present-day science, engineering and technology. It does imply, however, everything made subservient to long range flight—the maximum possible load of fuel, no head winds or adverse weather conditions, every element contributing to the desired result combined in the optimum manner and degree and everything operating with the highest attainable efficiency throughout the entire flight. It also implies flying constantly with a speed such that there will always obtain a certain fixed optimum ratio between two characteristic coefficients of airplane performance—the so-called lift and drag coefficients. The first of these relates the lift of the plane to the speed, to the wing area and to the density of the air in which the plane is moving. The second relates the drag, or resistance to motion, to the same conditions of the flight. Now it works out that for maximum range, or otherwise for maximum distance per pound of fuel, the ratio of these two coefficients—lift divided by drag, should be a maximum; and this implies a speed continuously changing with fuel consumption and with the consequent lightening of the plane—high speed at first when the plane is heavy and decreasing as the plane becomes lighter with the consumption of fuel but always so adjusted as to meet this condition between these two coefficients.

When we ask how near has present achievement approached such a range as 8,000 or 9,000 miles, we find a somewhat wider gap than for the case of speed. The present record is about 7,000 miles. When we realize, however, the remote chance, for a period of sixty to eighty hours, of a complete absence of all adverse weather conditions and a continuous perfect functioning, during this period, of all factors contributing to the desired end, the larger margin between actual and ideal performance is not surprising. It should also be noted that it is too much to expect practically a continuous exact regulation of the speed of the plane in relation to its weight in such way as to give the required relation between the two coefficients of lift and drag referred to above.

Again, it is obvious that a performance such as this is without commercial or economic value. The plane with only its operating personnel is all that reaches the ultimate point. For economic purposes, there must be something in the way of pay load and this necessarily reduces the possible supply of fuel and hence correspondingly, the distance which can be flown. Reference to this point has been already made in speaking of carrying capacity. Here again, it is clear that with a large fraction of the useful load allotted to fuel, the plane will be able to carry a small pay load a relatively long distance while with only a small part allotted to fuel, a large pay load can be carried a relatively short distance. The question of pay load and range are therefore mutually dependent, the one varying inversely as the other within the limits of the total useful load available.

When we pass, then, to the question of commercial possibilities, we find, for example, that the present *China Clippers,* making the flight across the Pacific in successive steps of which the longest is something over 2,000 miles, can, for this distance and with a reasonable margin of fuel for adverse weather conditions, carry only a pay load so small that, admirable as they have been as engineering structures, they can scarcely be considered as economically suited to this service. For successive steps of the order of 1,000 miles, on the other hand, they would presumably be found economically well suited.

It is confidently expected by both designers and operators that the new flying boats already referred to, with a total lift of 82,500 pounds and carrying some 10,000 pounds of pay load over a range of 2,400 miles at a speed of 150 miles per hour, will prove distinctly superior in economic performance to the smaller boats which they are expected to replace for this service.

When we come to the question of transatlantic service with an uninterrupted flight of about 3,000 miles, it will be safe to say that there are at present available no commercial craft capable of undertaking such service with a pay load sufficient to give assured promise of economic success. For step-wise flight by way of Bermuda and the Azores or for the shortest possible flight from Newfoundland to Ireland, there are possibilities. With reduced pay load or with no pay load, the transatlantic crossing is becoming almost a commonplace.

Earlier reference has been made to the competitive designs which have been called for, covering a structure which should give good promise of successful economic performance. It will be remembered that the specifications call for a structure weighing about 200,000 pounds and carrying a pay load of 25,000 pounds (including 100 passengers) at a cruising speed of 200 to 250 miles per hour and with a normal range of 3,700 miles but with fuel for a range in still air of 5,000 miles.

While we are thinking of the economic aspect of these matters, a few figures of cost may be of interest.

Thus if we take some of the most recent examples ranging in total lift from 42,000 pounds to the giant transatlantic plane of 200,000 pounds, we find investment costs range between $7.15 and $8.65 per pound of gross lift, making the cost of the *Boeing 307* of 42,000 pounds lift, $300,000, that of the new *D. C. 4* of 65,000 pounds lift (now undergoing trials) $470,000, that of the present *China Clippers* of 52,000 pounds lift, $450,000, that of the new *Boeing* boat, No. 314, of

82,520 pounds lift, $612,000 and an estimated cost of the proposed transatlantic craft of 200,000 pounds lift, $1,500,000.

For operation, the cost per hour for these planes, without stopping for the individual figures, ranges from $108 to $337 with a cost per mile from $1.62 to $1.23 and per passenger seat per mile from 1¼ cents to nearly 3 cents.

It is fair to say that the economics of these largest structures is by no means yet fully assured. Thus, estimate places the cost per seat mile for the new *Douglas 4* of 65,000 pounds total lift at 2.10 cents, which is practically the same as the figure 2.05 cents given for its predecessor the *Douglas 3*, with a total lift of only 24,000 pounds.

The same thought has apparently governed the design of a new *Curtis-Wright* thirty-passenger twin-engined plane which is approaching its first tests at St. Louis.

The total lift is 36,000 pounds with a cruising speed of 200 miles per hour at an altitude of 10,000 feet.

It appears to be a not unreasonable assumption that a structure of this relatively moderate size and capacity, but designed in the light of modern scientific advances, may prove economically well adapted to many types of air transport service.

Perhaps brief note may be made of a characteristic of airplane performance closely allied to range, that is, duration—the maximum time a plane can remain in the air regardless of distance flown. It will be seen that this characteristic is of no great economic significance. Obviously the economic purpose of an airplane is transport. It will be clear also that this requirement calls for the minimum consumption of fuel per unit of time rather than per unit of distance as in the case of range. Here again, if we assume everything subordinated to this one feature, and with similar assumption as before regarding the optimum combination of all factors affecting this one characteristic of performance, and likewise with no untoward weather conditions to influence the result—with all these conditions assumed, it again becomes possible to determine with a fair degree of approximation the maximum duration of flight—regardless of distance flown. The answer works out to be from 90 to 100 hours. The present record is in the neighborhood of 85 hours.

In connection with range, note was made of a condition to be fulfilled affecting the relation between the two coefficients of lift and drag, and it will be recalled that for maximum range the speed must always be such as to put the plane in an attitude of flight such that the ratio of these two coefficients has its maximum value. For maximum duration there is a similar condition, but not the same. For the latter the fraction which must have its maximum value has for its numerator the coefficient of lift multiplied by its own square root and for the denominator the coefficient of drag as before. It may also be noted that the speed of the plane will be less for maximum duration than for maximum range.

The gap between present record performance and the figures given above is again readily explained by the difficulty of insuring almost perfect functioning of all the factors entering into the final result during a period of say 60 to 100 hours, including the absence of untoward weather conditions, and further by the fact that, due to its small economic importance, there has been but little real

attempt to extend this particular performance to its ultimate limit. Range is a much more important item of performance for all economic and commercial purposes, and has, therefore, attracted the major effort in this direction.

Let us now turn to another item of airplane performance—altitude. How high can a plane rise above the level of the sea? The extreme achievement here can hardly be said to have any economic or commercial significance. So-called stratosphere or substratosphere flights, to which I shall recur in a moment, are in the immediate foreground of present-day practice; but the extreme of possible and even present achievement in this direction lies far beyond the possibilities of immediate utilization commercially.

As in the preceding case of extreme performance, we assume everythng about the plane and its loading made subservient to high altitude climb; and that these conditions are all combined in the optimum manner and degree and that throughout the climb all of these factors function together with the highest attainable efficiency. One more condition must be noted. The engine must be supercharged—that is, the air supplied to the engine for the combustion of the fuel must not be the thin rarefied air of the higher altitudes, but air at sea level pressure or as near to that condition as may be found attainable. The logic of the situation is clear. Power is developed through the combustion of fuel, that is, its chemical union with oxygen. A given volume of air is drawn into a cylinder of an airplane engine for every cycle of engine operation. Of this air about 23 percent is oxygen. At sea level pressure and density, this will provide for the burning of a proportionate amount of fuel with the corresponding development of power. The same volume of air drawn in at the density of 20,000 feet elevation would have only 53 percent of the weight of oxygen at sea level with a corresponding reduction in power developed. The corresponding figures for altitudes of 30,000, 40,000 and 50,000 feet would be respectively, 37, 24, and 15 percent of the oxygen at sea level.

It is, therefore, evident that if anything approaching full engine power is to be maintained at high altitudes, the air going to the engine must be precompressed to something approaching sea-level pressure and density. Or put otherwise, the more nearly these conditions can be approached, the greater the power developed at altitude and the higher the altitude ultimately reached.

So then, combining this condition with those previously noted, it works out that an altitude approaching 60,000 feet is within the framework of possible achievement without trespassing on what might be considered the fantastic. The present record is close to 53,000 feet (52,937) held by an English pilot.

There are many difficulties and limitations against which the struggle for high altitude must be made. Only a few of the more serious can be here noted.

1. Of the total power developed by the fuel burned, only a part can be used for climbing, since a part must be made available for the precompression of the air—a part which grows ever larger and larger the higher the altitude achieved.
2. No matter where it is in climbing flight, the weight of the plane together with the vertical component of the drag must be balanced by the reaction of the air on the plane together with the vertical component of the pull of the propeller. But the weight of the plane remains constant, except for the decrease by way of the combustion of fuel, while the density of the air, on which lift depends, grows less and less with increasing altitude, thus calling for higher and

> higher speeds through the air. The resistance to motion, for the same speed, is indeed correspondingly reduced, so that higher speed becomes possible; but the actual relations are complex and it works out that there is difficulty at the propeller (even with the modern controllable pitch forms) in transforming with high efficiency, such power as it receives from the engine into useful propulsive work; and this difficulty increases the higher the altitude. Add to these difficulties, reliable oxygen equipment for the pilot with clothing for protection against temperatures somewhere about sixty-seven degrees below zero, Fahrenheit, and it is seen that the attempt to scale the ultimate in airplane altitude carries a challenge which can only be met by a combination of adequate engineering design with supreme judgment, skill and daring on the part of the pilot.

This question of altitude flying brings us naturally to that of commercial flying at altitudes much less than those just noted, but still at an altitude which will permit of drawing a real advantage from the decreasing resistance to motion with decreasing density of the air and thus, within the conditions of commercial requirements, of realizing higher speeds of transport than would be possible [with the same engine power] at sea level. Already altitudes of 12,000 to 15,000 feet are the rule on long distance flights.

We remember that the word "stratosphere" is used for an indefinite stratum of the atmosphere lying above an altitude varying somewhere about 35,000 feet and above which the temperature of the air is nearly constant at about sixty-seven degrees below zero, Fahrenheit. Sub-stratosphere flights may then be considered as those made in that stratum of the atmosphere lying perhaps between altitudes of 20,000 and 30,000 feet; though undoubtedly first approaches will be made at somewhat lower altitudes.

Within these limits the difficulties which are met with at altitudes of 40,000 to 50,000 feet and above are present in lesser degree and it does appear possible to realize, commercially and economically, higher speeds of transport than at lower levels. The interaction of the various factors is quite complex and I shall make no attempt to discuss them in detail, but the general results of flights at altitudes of the order of 20,000 feet are already in the way of being put to commercial test.

For passenger transport, however, certain special conditions must be met. Most people can tolerate without difficulty altitudes of 10,000 to 12,000 feet. It is, of course, quite out of the question to provide passengers individually with oxygen masks and equipment. The only practicable solution for both passengers and operating personnel is to place the entire personnel, passengers and crew, within an air-tight compartment of the plane in which, above say 10,000 feet, the air is kept, by the operation of a suitable compressor, always at a pressure and density corresponding to this altitude. This means a closed metallic structure capable of withstanding the excess pressure within the cabin against the reduced external pressure of higher altitudes. Thus with the cabin at the pressure for 10,000 feet and with the plane at 20,000 feet, this excess would be about 500 pounds per square foot. With the plane at 30,000 feet, the corresponding figure would be about 800 pounds per square foot.

Then again the engine must have its own quota of air; but here no compression up to the conditions for 10,000 feet will be acceptable. Full sea-level

conditions or as nearly so as may be practicable will be required. All of this means, of course, extra weight of plane and mechanical equipment and here is where the limitation will enter with reference to extending such operation to extreme altitude. But this is only the beginning of difficulties. The excessive cold of these higher altitudes means again artificial heat for the personnel, trouble with gasoline and lubricants, with possible serious trouble in de-icing windows and pilots' lookouts.

However, all these are merely hurdles to be passed over and in the very near future we may expect to see such flights on a commercial basis, at least in the lower altitude ranges.

The first plane, presumably, to achieve this distinction will be the *Boeing No. 307*, which has been designed definitely with reference to this character of service. As already noted, this plane has an ordinary cruising speed of 175 to 180 miles per hour, and with 9,200 pounds of pay load, including thirty-three passengers, it will have a range of about 1,000 miles. I have already noted the cost of this plane, as $300,000, and it is understood that a certain number of these so-called "strato-liners" will very soon be put into actual service.

I have listed comfort as one of the requirements of air transport, but I shall not tarry long over this feature. It will be enough to say that the developments during the past ten years have held constantly in view increased comfort and convenience for the passenger. Sound proofing, reclining chairs by day or bunks for sleeping accommodations by night, meals as usual, the attentions of courteous and capable stewardess-hostesses—these, especially in modern large transport planes, have gone far to give to the air passenger a close approach to Pullman accommodations by rail, though naturally with less freedom of personal movement. Comfort and convenience, though counted on to attract and hold passenger patronage, are after all of minimum interest technically. It will always be a simple matter to provide these features, up to the limit of weight and space available, in competition with other and perhaps more important requirements.

We have thus passed rapidly in review some of the problems in modern air transport with indications of the direction of recent advance. We must now turn to what is, after all, the most important consideration of all and that is safety.

If we ask what is the most common menace to safety, the natural answer will be the weather. But the weather is simply one of the conditions under which the plane must render its service. Our guiding principle, in the matter of the relation between weather and safety, should, I think, be this: we must strive to secure a degree of safety in what we may call "proper flying weather" which will at least approach that in the safer modes of land travel; and we must strive to perfect our methods of observation and analysis of weather conditions and of the transmission and reception of such intelligence, to such degree as shall serve for a reasonably adequate determination of the quality of the weather over any proposed route with reference to this standard; and if, over the proposed route, the weather falls outside this characterization, the flight should be cancelled.

Now from the viewpoint of the plane and its services, in what way may accidents arise? Without attempting too much detail, we may say that accidents find their causes chiefly in:

Faulty areodynamic characteristics.
Failure of the structure.
Failure of motive power.
Failure of, or inadequate, navigational equipment.
Inadequate or erroneous information received from the services on the ground.
Human errors.

Again with regard to weather conditions, those which present major hazards are:

1. Rain, snow and fog, especially the two latter in degree requiring blind flying.
2. Violent winds, air vortices, extreme turbulence.
3. Temperature below freezing under atmospheric conditions which may involve the loading of the plane with ice or frozen snow.
4. The electrical state of the air—not primarily with reference to the hazard of a lightning stroke, but chiefly by reason of the interference with the services of radio communication.

A brief word with reference to these sources of potential hazard.

With our present knowledge of the aerodynamic characteristics required for safety and with the intensive study which is being given to refinements in these matters, we may, I think, feel confident that present design is and future design will be free of fault in its areodynamic characteristics in any degree likely, with proper handling to involve a major hazard in service.

With regard to the structure of the airplane, I think we may also say that the problems involved in the design and construction of the major parts of an airplane structure are now so well in hand that, in commercial service especially, major structural failures should become almost unknown. In this particular we may claim close approach to an entirely reassuring condition—a condition indicated by the rarity; in recent years, of accidents resulting from major failures of the structure of the plane itself.

Failure of the motive power, including engine and propeller, may have its source either in the structural elements themselves (for example a broken crankshaft or propeller blade) the exhaustion of the fuel supply, or in stoppage due to disturbance in the somewhat delicate conditions involved in carburation and ignition, or again in failure in the adequate lubrication of all rubbing surfaces.

Structually, the element of hazard here should be brought close to a point comparable with that in the main airplane structure. In the matter of operation, as long as we employ a type of fuel involving carburation and electric ignition, it now seems difficult to see how all hazard of interruption is to be avoided. However, an answer here is found in multiple power units. At the present time, the accepted standard in large air transport structures is four independent power units, any two of which should insure adequate power for the safe handling of the plane, at least to the nearest landing field. It seems hardly within the limits of probability that two power units would fall into trouble at the same time, and thus, with four such units, of which three or in any event two, would

always be available, we should have assurance of adequate power for safety under any conditions which can be foreseen.

Hazards resulting from carburation, ignition, and the danger of fire following a crash, could be minimized by the use of the Diesel type engine with fuels of the so-called safety type. At present, however, this would apparently involve some sacrifice either of performance or of pay load, and seemingly in our present temper we are slow to forego the service which present conditions give us, in exchange for this added margin of safety.

With regard to navigational equipment, there is no excuse for any lack of the best of such equipment now available, and certainly on all major lines of transport, there *is* no such lack. It is obvious that, at all times, the pilot must have the means of knowing his speed, his altitude, the direction in which he is flying and whether in a straight or curved path. He must also know where he is, as nearly as possible, and hence the distances and directions of nearby landing fields. He must also be able to ask for and receive information by radio on any and all matters affecting his flght.

Normal instrumental equipment with adequate services from the ground will give him all of this, except as weather conditions (fog, snow, electrical disturbances, etc.) may interfere.

There is room here, however, for improvement, and for which we may look with confidence in a near future. Especially is there room for improvement in ways and means for bringing a pilot from altitude, under blind flying conditions, to a safe landing on the field beneath him. It is relatively easy to guide a pilot to a point in the air over an airport. It is less easy to guide him down, blind, to a safety landing. Quite definite progress has been made toward the solution of this problem, but there is still room for improvement. At the present time, the chief navigational hazards result from conditions requiring blind flying and from electrical conditions of the atmosphere interfering with radio transmission and reception.

Steady improvement is being made in equipment designed to meet these and other conditions affecting safety, and only this past fall, four distinct advances in equipment making for safety have been announced. These are:

1. The radio echo altimeter for indicating the absolute distance from the ground, instead of the altitude above sea level, as with the standard type of instrument now used.
2. A new form of static suppressor which it is hoped will go far toward eliminating this serious hazard to radio communication between the plane and sources of needed information.
3. A new form of automatic direction finder for guiding the pilot to a source of radio wave with which he is in tune. This device may also be connected up with the automatic gyropilot in such way as to provide automatic blind flying toward the source of the radio waves.
4. A device for indicating approach to the dangerous condition known as the "stall"—meaning an approach to an angle of attack so great that the plane may pass out of control of the pilot and probably fall into a spin.

These are all steps forward along the general line of greater safety in air transport.

Turning for a moment to services on the ground, we find here, perhaps, at the present time, the largest opportunity for improvement. In recent years, funds far too small have been made available for improvement in the various agencies which are intended to supply the pilot at all times with reliable information on all matters affecting the safety of his flight. This condition must be corrected and improved; and with an adequate utilization of all that is now known and available in the science and art of meteorology, radio and airport equipment, causes of many casualties in the past would be removed.

There remain to be reckoned with, human errors. We can hardly hope that we can ever entirely eliminate this potential hazard to safety. Rigid requirements for license as a transport pilot with retests from time to time, have given us a highly trained and highly reliable body of pilots for this service; but there is, and, so far as I can see, there will always remain some residual hazard of human error—a hazard, however, which may be minimized in some degree by the presence always of a co-pilot ready to assume control in any case where corrective control might save the day.

Not to delay too long over this matter of safety, I can summarize my own feelings in the matter by saying that I cannot see, in any future within the scope of present vision, a reduction of the margin of air transport hazard to a point comparable with the safest of land transport means. There are too many additional avenues of potential hazard. On the other hand, there is hazard in all agencies of transport, a hazard in automobile transport for example; but we do not, on that account, hesitate to freely employ the automobile. In comparison with the service which it stands ready to afford, we accept this means of transport, with such marginal hazard as there may be. In the same way, it is obvious that the air traveling public now accepts such measure of hazard as may inhere in this mode of transport, in view of the service which the airplane is prepared to offer. And in this respect, I believe that we may look for continuing improvement in all of these matters affecting the safety and security of air transport; and that with the continued application of the resources of science and art to these problems, the residual margin of hazard in this form of transport will be reduced to a point where it will be accepted rather generally, and without hesitation in view of the service which it is prepared to render—possibly with almost the same readiness with which we now use the automobile in the affairs of our every day life.

In this connection some figures published in a recent report of the National Safety Council will be of interest. They are admittedly based on incomplete and somewhat uncertain data, but may, perhaps be accepted as showing the general trend. The figures in column *A* are passenger fatalities per 100,000,000 miles of travel; those in column *B* total fatalities, including operating personnel:

	A	*B*
Railroad trains	.09	9.9
Automobiles and buses	4.5	7.8
Scheduled air transport planes	10.1	13.5
Non-scheduled planes	162.2	165.2

Thus according to these figures, the hazard in scheduled aid transport planes is about twice that in automobiles and buses and about 100 times greater

than in railroad trains. It may also be noted that these figures are based on total estimated mileages as follows:

Railroad trains	22,460,000,000
Automobiles and busses	408,000,000,000
Scheduled air transport planes	435,740,000
Non-scheduled planes	99,900,000

The time which I should occupy in this address is near its term. Perhaps, however, I should say a word regarding lighter than air, the airship. The tragic end of the *Hindenburg* is still fresh in our minds as well as our own story of disaster in the *Shenandoah,* the *Akron* and more recently the *Macon.* Two questions present themselves. Can the airship be built with a reasonable margin of safety? and granting this, what is its promise for economic and effective commercial service?

First we must specify that the airship shall be inflated with helium gas. Our world monopoly of the supply of this gas is, of course, a matter of common knowledge. The use of this chemically inert gas will completely dispose of the hazard which caused the loss of the *Hindenburg,* inflated, as it was, with hydrogen gas. With this hazard eliminated, we have left the normal hazards of failure of the structure under adverse weather conditions. The record of the *Graf Zeppelin* in her around-the-world trip and later in regular commercial service between Germany and South America, together with the record of the *Hindenburg* aside from the fatal hydrogen conflagration, go far to prove, in commercial service, a high degree of safety and security. Thus, for the *Graf Zeppelin,* we have a record of about 17,000 hours of flying service over about 1,000,000 miles of distance, with safe carriage of 13,000 passengers on 144 ocean crossings. Similarly for the *Hindenburg* up to the time of her destruction, the record shows 3,000 hours in flight, 210,000 miles distance with the safe carriage of 3,059 passengers. Mention may also be made of the record of the small airships comprising our own Goodyear "blimp" fleet, with the appearance of which, at least, I presume we are all familiar. This shows, to the end of 1937, 122,379 flights covering 67,847 hours in the air, and 3,010,000 miles of distance, with a total of 302,248 passengers carried with no casualties or even injuries.

If you ask me to explain our own less favorable record with a loss of three naval ships out of four which we have operated, I could perhaps make the attempt, but it is too long a story. The designs of the *Akron* and *Macon,* the most recent ships designed and built in this country, date back now ten years. During that period we have learned much with regard to the hazards for which airships must be prepared. Especially is this the case with regard to the stresses on the control surfaces in gusty, turbulent air. We know now that the structure of these surfaces with their supporting framework in the case of the *Akron* and *Macon,* was not adequate to meet the stresses to which they might be subjected under such adverse weather conditions as must occasionally be accepted, especially when serving as an adjunct to a naval fleet, rather than on commercial service.

Not only has experience taught dearly bought lessons regarding these matters, but certain programs of research carried on in the Airship Institute at Akron,

Ohio, have thrown much additional light on this subject. Still other recent programs of research at the Goodyear Zeppelin Corporation in Akron have helped to bridge the gap between the loads which the elements of the structure must sustain and the dimensions of these elements in order that such loads may be carried with a suitable margin of safety.

The story is too long and the subject is too complex for any discussion in detail. I believe, however, that a fair conclusion is that with the full utilization of recent advances in both the science and art of airship design and construction, we can now design and build airships with a margin of structural safety and security at least equal to that for the airplane. So far as further comparison goes, the airship is relieved of two possible hazards affecting the airplane—propulsive failure followed by a forced landing, and control failure followed by the too often fatal spin.

On the whole, there seems to be no reason why our future airships—in case any such be built—should not show an excellent record as regards safety and security in operation.

With regard to the field for successful commercial service, present opinion in the United States is divided. I shall not take the time to discuss the pros and cons but will only venture my own opinion that for transocean service on relatively long non-stop runs (3,000 to 6,000 miles) with relatively heavy loads at speeds three times those of surface ships though perhaps only one-half to one-third those of the airplane, but with greater passenger freedom and comfort than for the airplane, there may well be found a useful and effective place for the airship in our complex system of modern transport.

Something might also be said regarding the possible use of the airship in naval warfare; but here again the question is highly controversial and I shall not venture into this domain.

Perhaps, also, if you will bear with me, I should say a word about the autogyro and the helicopter. The former is sustained by rotating wings or vanes, maintained in rotation by the motion of the structure under the pull of an air propeller, driven by an engine much as in the conventional airplane.

The latter is, in effect, simply a flying propeller. The shaft, nearly vertical, is tilted so that the upward component of the total pull provides sustentation, while the horizontal component provides transport.

The autogyro, now some fifteen years old, seems to be in the way of acquiring a fairly well assured place among the varied forms of aircraft available for air transport. It appears to have special qualities which go far to adapt it to individual use; take-off from and landing in confined areas and relative safety against casualty from loss of control as may occur with conventional airplane forms. Present speeds are moderate—125 miles per hour perhaps—and it is not easy to see, in this type of construction, a serious rival to the conventional form for either high speed or heavy weight carrying, as in the modern conventional forms referred to earlier. As a relatively safe "family carriage," however, this type does appear to have possibilities, and its future development will bear close watch.

(*Please turn to page 57*)

WHAT HAS BECOME OF REALITY IN MODERN PHYSICS?*

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In starting to prepare an address having to do with reality it seems not inappropriate to go to the dictionary and see what it has to say about the word, so I went to the dictionary. I will not tell you all that it said. It seemed to be having a hard time trying to say anything; and, indeed, I came to wonder whether the dictionary would permit me to say that the moon is real. I became more convinced of the truth of a statement I have had occasion to make several times during the past few years, and to the effect that "words are merely imitative grunts invented by mankind for the purpose of putting minds into harmony with one another." They are the catalysts of thought; but, it always remains for the parties concerned to become adjusted in their thinking, so that each gains a correct comprehension of what the other wishes to convey.

Any fairly general concept such as that of reality is apt to have about it, in addition to the elements which really matter, other elements of an irrelevant nature. These irrelevant garnishings frequently asborb most of the limelight; and, being frail tinselled things of the type which catch the eye of the mind most readily, they are the things most vulnerable to the attack of anyone who sets out to question the logical meaning of the concept and the basic foundations beneath it. Even as the eye of vision sees more readily the surface of things than the structure within, and seeing that surface sees frequently for the most part the dust of other things which has fallen upon it rather than its true self, so the eye of the mind, in looking at the concepts of nature, sees first the surface rather than the inner structure which binds it together; and, in that surface itself sees many things which have fallen upon it and become entangled with it, but are no part of its fundamental nature. Sometimes it is difficult to find the real working element which forms the essential part of a concept on account of its complete entanglement with the irrelevant parts which obscure it.

There are three states of sophistication in physics, and particularly in modern physics. In the first, one accepts, in a superficial way, everything at face value. In the second, he sees that many of the verbal statements require qualification. Some of the concepts are not unambiguous in meaning. Certain conclusions are limited in their validity. The significance of the statements is not quite what is implied by the words. The arguments presented are not a proof of something, but an analytic expression of a hypothesis, and so forth. In this state of sophistication one frequently thinks by analogy in the belief that concepts with which he is familiar in one line of knowledge can be transported without change to another. State of sophistication No. 2 is destructive rather than constructive. There is a tendency to look, not for the rose, but for the thorns.

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Those in state No. 1 are the natural prey of those in state No. 2. The latter can quite readily knock all the arguments of the former into a cocked hat, and can show that everything they say is illogical, meaningless, and contradictory. Unfortunately, those in the realm No. 2 are apt to vision the complete defeat of those in realm No. 1 as the ultimate goal to be attained. In state of sophistication No. 3, one admits many of the points raised in state No. 2, but realizes that the essence of the theories under discussion lies in realms other than those in which one in state No. 2 is looking for them. A member of state No. 2 says to a member of No. 1, "You are a fool, and a waster of the time of yourself and everybody else. Your arguments are illogical and your theories are all nonsense." One in realm No. 3 is more sympathetic. He says to the disconsolate resident of state No. 1: "My friend, your language is terribly muddled. You do not propose to yourself quite the right questions, nor do you give quite the right answers to the questions you do propose. Now in connection with this matter, for instance, what you really should have said is such-and-such." No. 3 admits that there was something to be said in that vicinity, and he criticizes only the method of saying it. In state No. 3 one looks in the muddled structure of state No. 1 for the real thought structure which binds the facts together as with bars of solid steel. He sees that the denizens of No. 1 have painted the steel bars with gold paint to call attention to them, that they have inadvertently rotted them through in certain places and spilt some of the paint in all sorts of other places all over the structure. In state No. 2 one complains of the gold and says that it would not serve to hold the structure together. In state No. 3 one sees that the gold paint is really irrelevant.

If I raise with you the question of whether I am in reality here this evening, you will probably believe that there is no question about the matter. You will assert that you see me here, a three dimensional object, with length, breadth, and thickness, emitting those imitative grunts to which I have referred and which you are conscious of hearing. What can constitute more satisfying evidence as to my presence? Alas, I have to inform you that, without going further into philosophy than is involved in the elementary principles of high school physics, you see me twice over, once in each eye, you see me as two-dimensional images upon the retinas of your eyes, you see me upside down, and that which the left eye sees the right-hand side of the brain interprets. My presence here is really a very doubtful and complicated affair, and I am so perturbed as to the reality of my own existence that I am tempted to seek the confidence of words, if you ask where and what I am, by exclaiming with Popeye the Sailor, "I yam what I yam, and what I yam, I yam."

If I were a mythological or a theological being, you could thump the table in righteous indignation at any suggestion to the effect that I do not exist and bring the fear of eternal punishment to the hearts of all who would for a moment permit such a heresy to ccupy their thoughts. Your minds would be closed to the search, and you would be saved needless worry. Since, however, I am but a humble man of science, you cannot so easily escape the necessity of

saying what you mean by my presence, and you will not be subjected to such pains and penalties by questioning my existence.

Now, in spite of all the difficulties I have raised as to the reality of my presence, the fact is that you seem to have had no doubt about it, otherwise you would not be here—if, indeed, you are here. In state of sophistication No. 1, I should never have had any trouble about the matter. In state of sophistication No. 2, I am highly elated at the possible deception I have perpetrated upon you in making you believe that I am here, and in the deception I have perpetrated upon myself in becoming conscious of the fact that I am talking to you when you may not be here at all. In state No. 2, I cry aloud: "The gods be praised, we are all mad!" In state No. 3, I pin myself solidly to the faith that there is really something to be said about the matter, even though we are all under an illusion as to what it is and as to what is going on. I will at least seek elements in terms of which to correlate the illusions, if I find them; then, in state No. 3, these elements shall, indeed, be the things which are real. A denizen of state No. 1 will probably be much bewildered by them. For his comfort, I shall probably try and piece them together in some kind of way which will recreate things which will correspond to and be representative of his somewhat naive thoughts. A denizen of state No. 2 will probably call me a metaphysician; or, if he gets to the point of understanding what I am talking about, he will look for fresh trouble there. But, in state No. 3, I shall occasionally do things for which one in state No. 2 will scorn me. I shall think sometimes even as the simple fellow in state No. 1 thinks. My extra strength will lie in the continual caution which, while permitting me to stimulate my brains with the naive thoughts of state No. 1, will keep those thoughts as my servants rather than as my masters, and will enable me to know when one of them is liable to lead me astray.

If you think it is my purpose this evening to delve into the morasses of scientific theories and philosophic thought and bring forth, cleaned up for your inspection, something of which I can say: "Here is reality, it was covered with dirt and mildew, so that you could not see it. Now, that it is cleaned and free from grime, you recognize it as something which you have long known and for which you were looking"—if you believe this, you are doomed to disappointment. No, my mission must be other than this. I am as one who, in the midst of his labors, is called upon by a professor of English, who says: "My dear friend, I have here a word, 'reality.' It is a very old word and I hate to throw it away. Can you find in your science something which you can christen with this word? It is a word which has been used much, but I have heard you say that its uses have been inconsistently made, and that you have threatened to take away its job and have it removed from the dictionary. I ask you not to give it back its old job, for you tell me it really had no job at all. I beg of you, however, for the sake of history and for the dignity of the dictionary to provide something for it to do." I am fond of my friend, the professor of English. His subject has been responsible for many beautiful things in life, and I shall try to accommodate him.

It may be worth while to pause for a moment, and, without criticism of his reasons or motives, enquire what criteria man has in the past been accustomed to use as a guarantee for the reality of things. In spite of the remarks I have already made throwing doubts upon your justification for believing that I am here this evening, I suppose the most common evidence which man has accepted in the past as to the reality of anything is the evidence of his eyes. If he can see it, it is real. Truly, he has had to qualify this attitude occasionally, for even a cat soon finds that it is useless to try and fight what it sees in the mirror. If you raised the question of the mirror to one who was content with what he saw, he would probably have to retrench a little to the extent of saying that if a thing could be seen, the fact constituted evidence of its existence, but not necessarily of the position that it occupied. Then I suppose the sense of touch has provided another criterion. If you can feel a thing, it must be there. Here again I fear a few reservations are necessary, for I have heard tales of a man suffering pains in a big toe which had been amputated several years previously. One who relied upon the sense of touch would have to retrench a little more than he who relied upon the sense of sight; for, in the instance cited, the best he could say would be that his sensations were evidence that there was a big toe which had been real. The remaining three senses, smell, taste, and hearing, have all, in varying degree, and with their appropriate reservations, served to provide man with criteria for what he calls the reality of things.

When we pass from the direct evidence of our senses to the next realm of criteria, we come to such evidence as that which I have for the existence of New Zealand, which I have never seen, touched, smelt, tasted, or heard, for I have never been there. Somebody once told me there was such a place. He may have said that to deceive me, but such a lot of other things connected with the assumed place and with people who are said to have come from there have come to my notice, and I can correlate all of these things by supposing New Zealand to exist. This is an example of adoption of a criterion of reality founded upon the fact that the assumption of the existence of the thing in question harmonizes a number of phenomena. It is quite true that in the case of New Zealand the said harmonization was enhanced as a criterion of reality of that land by the fact that a lot of my friends have seen it even though I have not. We can, however, cite instances of similar situations in which harmonization of events has been taken for the criterion for reality of something which nobody had ever seen, or at any rate, which nobody had seen at the time when the criterion was accepted. One of the most famous illustrations of this kind is that associated with the discovery of the planet Neptune. The heavenly bodies were found to move in accordance with certain elegant laws, prominent among which was the law of gravitation. On closer examination, it was found that they did not move quite in the manner expected. It was found, however, that by postulating the existence of another planet, Neptune, order could once more be restored. Of course, an alternative method would have been that of changing the law of gravitation. This would have involved a hopelessly complicated adjustment, and the fact that the postulation of Neptune provided a relatively simple adjustment caused mankind to accept that postulate. Of course,

following the calculations, Neptune was looked for and found. In other words, the adoption of one criterion for its existence was followed by the discovery that another already accepted criterion, that of seeing it was satisfied. However, even had Neptune been made of invisible substance so that no one could ever see it, there would have been meaning to the postulation of its existence as a coordinator of the planetary motions. If I ask you to believe that Neptune is real on this criterion alone, I cannot demand that you accept the criterion. Your acceptance or refusal must depend upon your own psychology. If, like St. Thomas, you must touch to believe, I have nothing to say to your objections. This does not prevent me from adopting the gravitational criterion as my own evidence of the reality of Neptune; and if you worry me too much with objections I shall be perfectly willing to present you with the word "reality," or with my share of it for such enjoyment as you may obtain from its contemplation, confident in the fact that whether I call Neptune real or not will have little effect upon my calculations. My nautical almanac will be well prepared in spite of what you may think of my halucinations with regard to its origin.

Following the reorganization of scientific thought which came as a result of the work of Newton and Galileo, science concerned itself for a considerable time with the laws pertaining to matter in bulk, where questions of reality did not seem to invite very stringent attention. It is true that even in Newton's time questions as to whether light was attributable to certain hypothetical particles or to waves in a hypothetical medium were upon the board for discussion; but, the knowledge of the times was not sufficient to develop all of the necessary consequences which would be demanded of the particles or of the waves, and which in their demands might raise questions as to their reality as they have done in recent years. It was sufficient at the time to think of some kind of a medium capable of transmitting wave-like phenomena in the same kind of way that water transmits waves or that solids transmit waves. Only in later years did the more careful analysis of the necessary properties of the medium demand that it should behave in a manner so different from any substance with which we are acquainted as to raise the question of whether it should be called real or not.

For the most part, however, men of science were concerned with the motions of the heavenly bodies, the phenomena of the tides, the vibrations of air in sound, and the like; and, while a conscientious philosopher might at any stage of the procedure demand considerations concerned with the reality of things, these considerations did not force themselves upon us. As the laws of the coarse-grained phenomena of matter became further ferreted out, however, there came a time when, in order to correlate even many of the phenomena which our eyes witnessed, it was necessary to introduce a sub-grained mechanism which was itself invisible and imperceptible to our senses in the details of its supposed actions. First, there came the rather vague concepts of atoms and molecules. We could explain the pressure of a gas contained in a closed vessel by supposing it to consist of a large number of individual particles flying about in all directions with high speed, bombarding the walls of the vessel, and producing thereon the equivalent of a steady pressure as would a stream of sand directed against

the wall produce such a pressure. The fact that the pressure exerted by a given quantity of gas is inversely proportional to its volume was readily explained by this view; and, by correlating temperature with the average kinetic energy of the particles the relation between pressure and temperature was also provided for. In all of these matters, and in many of their extensions, it was not necessary to endow the particles with any properties other than that of the power to possess inertia, so that what was demanded of them was so like what was to be found in large bodies which could be seen that the demand carried no implications which invited questions as to the reality of the particles.

In the science of chemistry, a correlation of the observed phenomena demanded a richer set of properties for the particles than was required by the kinetic theory of gases; but, here the properties found their expression in more or less empirical form without the invocation of any detailed form of mechanism to account for them. It was as though the chemist said: "The behavior of the various atoms and molecules can be accounted for provided that we postulate them to be things which can do this and that. Perhaps some day the physicist will find how they can do it without offending our susceptibilities; but, whether he does or not, we do not care very much. We have a means of making our chemical compounds." You see, the chemist is the lineal offspring of the alchemist, and until he became converted by contact with the physicist he was content and happy in the application of his collected receipts for the manufacture of his nostrums.

In addition to chemical phenomena, however, we became involved in increasing degree with others having to do with the kind of light emitted by incandescent gases. The spectrum of this light showed lines which were arranged in groups of great complexity but, nevertheless, of very characteristic regularity. This structure, so unambiguously evident to the eye, seemed to call for some equally unambiguous mechanism to account for it, and there seemed no place to look for this mechanism other than in the sub-grained structure of the atom itself. The first hopes were in the direction of building for the atom a vibrational structure, or a structure capable of emitting vibrations to some all-pervading medium, and founded upon such mechanisms as were already familiar to us in the observable phenomena of nature. We should have liked to see the atom working as a dynamo works, or as a watch works, or as the ripples upon a bowl of water work, or as the solar system works. Suppose we had been successful. What would have been our attitude towards the reality of these sub-grained structures which we could not see and could never hope to see? I think we should have been in the position of one who had discovered Neptune by calculation, but had no means of seeing it. I cannot tell you whether, under these conditions, it would have been appropriate for you to call the atomic structure real or not. Before I can tell you that, you must first give me your criteria of reality. I think that in this you will find some difficulty. You will start off, possibly with a feeling of irritation and in the temptation to say, "Every fool knows whether a thing is real or not"; but, when I ask you to state your criteria for the reality of the parts of this mechanism, the thought may first pass through your head that you would like to smell them. After all,

that is the criterion that most *animals* seem to apply concerning the reality of things. Realizing that this demand is perhaps inappropriate and that you must further admit that the parts of the atom are too small to see or to feel, you will begin to talk, subconsciously to yourselves if not to me, about what the parts of the atom would smell like or look like if you could really make them big enough to have an odor or an appearance. If I hear your thoughts in the matter, I fear I shall have to disconcert you by suggesting that possibly the sense of smell is concerned with the activities of the atom as a whole, and that it would be as meaningless to talk about the odor of one of its parts as it would be to talk about the scheme of administration of the propeller of an airplane because there was sense to talking about the scheme of administration of the army of which the airplane forms a part. The fact is that on seeking to rejuvenate your idea of the reality of things, you attempt to accompany the act of magnifying the parts of the atom by the endowment of those parts with the kind of attributes which are the attributes of the atom as a whole. I fear that if you should try to state your criteria for the reality of the parts of the atom which I have envisioned, you would find that you would have to discard one by one the things which you had subconsciously felt were relevant, until finally you were left with no more than I claimed at the start, the bare properties of the parts of the atom necessary for the functions demanded of them and without extraneous adornment. Again, I say the question of whether you should now call these things real or not is one concerned with our conventions as to the use of words. You must settle that matter with the author of the dictionary, rather than with the philosopher.

It is true that in adopting the artifice of envisioning a sub-grained mechanism, imperceptible directly to our senses, to account for large scale phenomena which do affect our senses, we are open to a possible ambiguity in that there may be more than one sub-grained mechanism which will fill the needs. One might be tempted to maintain that only one of these sub-grained mechanisms can be the real one which actually exists. I think I might devote a good part of this lecture to analyzing that contention and to supporting the view that under the conditions cited one might refer to all of the mechanisms as equally real. I must not succumb to this temptation now because I have other matters to discuss. I will return to it; but, I may say that to worry about the apparent ambiguity would be like worrying about whether it was the Emperor of France or the General in Chief of the French Armies who was unhappy after the Battle of Waterloo.

Now, in the attempts which were made towards visioning a structure for the atom along the lines I have so far cited, the parts of the atom with which we dealt did obey some of the laws which are familiar to us in the large scale things of life. In picturing a structure which was something like the solar system, with particles rotating round a central body analogous to the sun, we did not demand that those particles have upon them mountains, rivers, green fields, and other people who are also studying atoms; but, we did envision that at least as regards the motions of these particles in relation to their common center there was some similarity to the form and type with which we were familiar in

the large scale things of life, in astronomy, for example. However, it turned out that in our search for a theory of the atom, the necessities of the facts drove us even further from the kind of structure which is familiar to us in the large scale things of nature than the naïve mechanistic structure to which I have just referred, but without specification in detailed form.

In speaking of the changes of attitude which accompanied the development of atomic concepts from those following the lines of the older mechanics to the kind of concepts envisioned today, it is perhaps well to pause and comment upon what it is that limits in our mind the arguments which are to be regarded as natural and appropriate to any field; for, it must be emphasized at once that the modern theories of the atom are in no way more lacking in richness of law content or in definiteness of statement of behavior in terms of our observations than were those which represented the attempts of earlier days. Indeed, they are more explicit in the story. I exclude, for a moment, matters having to do with statistical considerations so frequently employed in modern theories; for, although there is a certain indeterminism involved, this indeterminism is itself an ordered thing and is not symbolic of chaos in the mental processes of the mathematicians, but has its counterpart in the limitations of possibilities in our observations.

It is an ideal to believe that the laws of all phenomena can be included under one general scheme. It is an ideal to believe that in the light of this scheme the general principles, for example, which the artist tries to instill into the pupil whom he is teaching to paint, and the general prnciples of harmony, counter-point, and the other abstruse elements of musical composition, and the principles involved in the construction of an automobile or a steam engine, are all brothers related to one another in as definite a manner as today we recognize the relationship between the mechanical performances of an aeroplane and autogiro. In spite of this ideal, whose merit is, however, questionable, the fact is that people talk in different languages in different fields. While, as a man of science and a student of physics in particular, I must be skeptical about the artist who shows me his old violin, tells me that it is better than any other because it was made by Antonio Stradivari over 200 years ago and because it has some of the soul of the maker in it, and because it is patterned after the form of the Virgin Mary—while I am skeptical of all this, I must believe that the owner is trying to say something which has meaning. I know him quite well. He is a very intelligent and delightful person. He is certainly no fool; and, faced with the idea that the violin really sounds good and that it can fetch $50,000, I must be persuaded that unless I am willing to believe that all are mad who would pay $50,000 for it (and much madness is necessary to waste $50,000) there must be something in what he says. I cannot accept his reasons; but, I have to accept the fact that the language he talks is the language which enables people to act in relation to the acquirement of and performance upon violins.

I have a darky chauffeur, and when anything goes wrong with the car, he seems to be able to put it right. This extends even to the principles of operation of the electrical parts. Now in giving his opinion as to what is wrong and his reason for what he does to put it right, he talks the most extraordinary set of

principles of electricity that I have ever heard. Nowhere in any textbook on physics have I seen anything like them; but he applies them, and the car goes. Sometimes I am inclined to think that for that limited field of electricity applicable to automobiles and to my machine in particular, his fundamental principles of electricity are better than mine.

And so the reasons which seem "reasonable" for the explanation of things vary very much in the different fields of culture and learning. We may contend as strongly as we wish that this should not be so and need not be so, but it is a fact that it is so. Moreover, the "reasons" for things associated with any particular field are apt to become rather sharply circumscribed, so that relatively minor deviations from the nature of the "reasons" introduce elements of artificiality to students of the field concerned, and tend to endow the unfamiliar concepts with elements of what we call unreality. With such varied reasons as we encounter for the behavior of things in different fields, it is not surprising that the nature of the reasons palatable to us in any one field itself is apt to change from epoch to epoch, from decade to decade, and even, in these times of rapid advance, from year to year. The abstruse things of today, become the common-sense things of tomorrow. With pains and pangs does the mind sometimes follow these changes; for the mind is what we may call a progressively conservative thing; and, it is apt today to become extremely conservative in its radicalism of yesterday.

And so in the minds of those scholars of the last century who concerned themselves with the realm of the atom, the strain of thought which was "reasonable" was one in which the story of what happened was told in the motions of things, the story of these motions themselves being told in terms of the relationships of the things which moved to other things in the structure and to each other. The motions of the planetary bodies at any instant were described in terms of their positions in relation to the sun. That which happened to the motion of a planet at any instant could be calculated from its position in relation to the sun. The concept was that of the sun being "responsible" for the motion of the planet. In the customary language of the times, and even of today, for that matter, it was one in which the sun was said to produce a "force" on the planet, which force was responsible for the change of motion occurring in the planet at that instant. Much thought was expended even in this matter for the purpose of realizing some kind of continuity of medium between the planet and the sun by which the force could be transmitted in such a manner as to make it more analogous in its behavior to the forces which are transmitted through a piece of elastic when it is pulled, or through a rod when one end is pushed. It is quite true that even the transmission of forces through rods was not something without further need of clarification. Speaking of cohesion, which is the property involved in the transmission of this force, Sir Oliver Lodge once remarked that it was still an inexplicable thing as to why, when one end of a rod was pushed, the other end moved, to which the celebrated comic periodical "Punch" replied that it was an equally inexplicable thing as to why when one end of a man is trodden upon the other end shouts.

And so the ideas of astronomy sought a place in the atom. There were things which moved—electrons, and the like—and it was sought to express

their motions in terms of their relative positions in relation to one another. It was hoped that the motions would tell the necessary story if we caused the atom to be pictured as existing in an all-pervading medium, an aether, so that the moving parts transmitted some of their motions to the aether, which then carried the story to all the other atoms in the universe, including those of our measuring apparatus, and those of our own substance. In the picture created, much of what constituted the naïve concept of reality had already evaporated. We had become content to seek in the particles which constituted our atom no properties other than were required for their functions. We were not troubled as to the color of the electron or as to the question of what it was made of. We had become satisfied that those questions really had no answers. The aether gave trouble for a long time, because it seemed so *very* unreal. We were content not to worry about such questions as what its boiling point might be, and as to whether in the extreme cold of interstellar space there might be icebergs of aether moving about, since everything else would freeze at such temperatures. We were content to avoid spoiling it by forcing upon it all sorts of properties extraneous to its functions, simply because ordinary matter had those properties; but, the thing that made it seem so very unreal was the fact that even the properties it *had* to have were so very different from the properties that anything else which we knew had that it was hard to accommodate it in the realm of respectable realities. It was not even a respectable ghost; for, though a ghost lacks much of substance in a living being he at least seeks to clank his chains in some sort of imitation of what he would do if he were alive. It was, I believe, Lord Salisbury who once defined aether as "a word devised to provide a nominative case to the verb 'to undulate.'"

Even with all the foregoing concessions in respect of freeing the necessary elements of the atomic world from too many of the embarrassing characteristics which we had been accustomed to associate with reality, it still refused to work properly. The motions of the parts of the atoms didn't do the right things and the aether didn't transmit the story in the right way, so that towards the end of this period of thought, I was constrained to give another definition of the aether which I hope you will pardon me for repeating here. "The aether is a medium invented by man for the purpose of propagating his misconceptions from one place to another." This was in the prohibition era, so I added the observation that "Of all subtle fluids invented for the stimulation of the imagination, it is the only one which so far has not been prohibited."

When it appeared that the types of mechanism to which I have referred could not be strained in any reasonable way to tell the story desired, a change in the mode of thinking became inevitable. However, drastic as that change appeared at the time, it was a timid change as we see things today. The electrons and so forth in the atom were allowed the prestige of continuing to occupy it and of conforming to some of their rituals of the past, as exemplified by their obedience to the old laws of motion. However, when it became necessary for them to do anything which really mattered, it also became necessary for them to do that thing in a manner governed by no scheme of forces with actions anything like those of our previous pictures. The atom was supposed capable of existing in a number of different states, in each of which it carried out the

ritual of the older laws, but did not do anything of importance. It was supposed, however, that a kind of revolution could occur at any time which would convey the atom from one state to another. The story of the revolution itself was not contained in the atom's ritual. The atom was like a capricious coquette, who could change from the state of life of a party-going débutante, to a social worker, or a domestic servant, with no other reason given than the fact that on each occasion she changed her mind. It is true, that we tried to investigate what was involved in that change of mind. We were able to relate her changes of mind in part to external influences, but influences which operated according to no laws simply related to the laws which governed the ritual of her existence in any of the states into which she, from time to time, settled down. Even with this widening of possibilities as to the nature of the external influence, the external influence was not enough, and a goodly element had to be left to her own capriciousness which defied all attempts at harmonization in reason. Physicists will recognize that these changes of states of existence and the chances of their occurrence are symbolic of what is involved in the spontaneous and induced Einstein probability transitions in the case of the atom.

As we contemplated the atom in this stage of development of our theories, we saw a rather patched affair., The old rituals, which we had formerly hoped would accomplish everything, accomplished little but the provision of states of dignity, and the interesting things were done according to the new principles. As we came to look closer into the matter, we came even to doubt whether these old dignitaries which occupied the atom of our old picture were really now doing anything at all but look on and maintain as far as possible the atmosphere of older times to give man comfort in, alas, the false belief that the new things were being done under the authority of the old régime. The atom was something like an old government institution with a lot of old gentlemen, who are really due for retirement, hanging around in apparently important positions, because nobody has the heart to discharge them, doing really nothing and not even controlling the policies of the organization any more, but extremely meticulous about the appointments of the smoking room, the maintenance of the architectural form of the building, and the preservation of certain traditional functions which spoke the glories of the times when they themselves were in action.

If now you ask me whether these old denizens of the atom were to be regarded as real, I have to answer in something like the manner in which I would answer the question of whether these old gentlemen to whom I have referred were really alive, and whether they really were the functionaries listed in the official record. I should have to say: "Well, Mr. X is nominally head of the department you are speaking of, but Mr. Y is the actual head. Mr. X really doesn't do anything." Even this analogy is a little too strong in favor of Mr. X, as a representative of his counterpart in the atom, because Mr. X continues to have certain attributes which, while not part of his official functions, nevertheless enable me to recognize his existence. He has a nice white beard which I can see. He has a nice polished bald head which performs the function extraneous to the activities of the department of reflecting the light of the sun with great intensity. No, if I am to use Mr. X as my analogue of some of the things in the atom, I must ask you to allow me first to kill him. Then I shall say: "The

spirit of Mr. X is still felt in this organization. His deeds will never die. His name is immortal, and his influence is here today." Now, if you ask me whether the ghost of Mr. X is real or not, you ask me the same kind of question that you ask when you demand to know whether some of those concepts in the atom of which I have spoken were, or I may even say, are in actuality there.

Now the modern age differs from that of the intermediate age in the acquirement of a greater ruthlessness. The rituals performed by the old gentlemen in the atom took up too much space. They interfered with too many of the necessary functions, and they have had to be abolished. The activities of the atom have been reformulated with a view only to their efficiency as regards the work to be done. There still remain *some* ghosts of the old picture. There was some truth and meaning, as well as extraneous meaningless adornment, in the atomic organization at the period in which I have likened it to the office peopled by the old gentlemen and the younger workers aforesaid. In the newer school, however, we have tried to dissect out the essential elements and cut off everything which is an encumbrance. With the extra room and freedom from the constraint of the old rituals provided in this way, we have been able to enrich the harmony of relationships between the different things with which the atom is concerned. There still remains the concept of what I may call various states of dignity in the atom. The young lady of my former analogy still exists sometimes as a party-going débutante, sometimes as a social worker, and sometimes as a servant. We still have no "reason," *in the old sense*, for her changes of mind which take her from one to the other. We have, however, come to realize that there never could have been any reason, in the old sense, for these changes. (I apologize to the ladies for the femininity of my illustration. I beg you to believe that the more I dematerialize the atom, and make its laws more ethereal, or may I say spiritual, the more I find it necessary to endow it with feminine characteristics—the bad with the good.) However, while we have given up seeking a reason for the changes of mind of the lady concerned in terms of our old laws of forces, or what in my analogy I may call "rigid parental control," we have come to some success in being able to predict what the good lady is likely to do. The laws of this prediction are founded upon what I may call "laws of temptation." In any one state of the lady's existence—in any one state of the atom—there is a temptation to change to any one of the other possible states of existence, anod we have discovered how to calculate the extent of the temptation.

I am getting a little mixed up between the old gentlemen and the young ladies. However, if you recall my language, you will realize that the young lady has been represented rather as the atom as a whole without any implications as to materialism of its parts. This young lady, the atom, is the goddess to whom we pray to give us an answer to what we may expect when we look at something which is very different from an atom, an exploding star, or when we look at the aurora borealis, or at some instrument in our laboratories which is said to be recording something about cosmic-rays. On the other hand, the old gentlemen were symbolic rather of those thoughts of material things of which the atom was, in former days, supposed to be made. Even today, the relics of these old gentlemen are left. As I have said, their former rituals of the inter-

mediate stage of development have been abolished, not because they did anything, but rather because they got in the way of what was to be done. However, names still hang about the office of the atom. Only the portraits of the old gentlemen are on the walls, but when the atom is allowed to do anything in our mathematical calculations, we still, as a matter of courtesy, go to the room of the old gentleman who in the old days tried to do that thing; we bow to his portrait, and send out the order for action, telling the world that it came from him. Or, to return to the reality of expression, if not of things, when a quantum of light comes out from an atom we say that an electron sent it out, although, if we trace in our thoughts the mechanisms of our calculaions, we shall find that the electron did no more than was done by the portrait of the old gentleman to whom I have referred.

Not only in the realm of what we formerly called things has the significance of reality passed in the last few decades through the rigid fire of critical examination, but in the realm of concepts also the like has occurred. There was a time when, in making the statement that a body was absolutely at rest in space, we said something which we thought had meaning. There was a time when the time interval between two events, the explosion of two stars in the heavens, for example, was supposed to have absolute meaning, regardless of who measured the time intervals concerned. Of course, if I measure the time interval and the stars are at vastly different distances from me, I am constrained to think that in order to get correct measurements I must allow for the fact that the light from one star took longer to reach me than did the light from the other. In former days, there was a kind of feeling that when this correction was properly made we should arrive at a unique meaning for the absolute time interval between the events. It turned out, however, that nature seemed to work in such a way that if I should make this measurement, correct it for light velocity, and arrive at this time interval between events, and if somebody else, moving relatively to me with constant veloeity, should do the same thing, the results for the much desired true time interval would be different. According to the old view of things, if you formed the old concept to the effect that I was at rest, you would readily seek to explain the difference by saying that the other man was in motion and, therefore, used the wrong value of the velocity of light in making his correction for time lag between stars. However, a more careful analysis of the situation, made on the basis of the facts of experiment, led us to conclude that there is nothing that I can do to prove that my measurements and calculations are correct that the other man cannot do to prove that his are correct. When the attempt is made to resolve this apparent paradox, one comes to realize that there was nothing to the intuition which we formerly had as to there being an absolute meaning to the time interval between the events, and it turns out further that there was no meaning to be attached to the absolute velocity of a body in space.

Time, at least as you measure it, will not permit that I extend this lecture into a discussion of the principles of relativity. I may perhaps cite a very crude analogy which will perhaps give to those unfamiliar with the subject some com-

fort to counteract what may otherwise appear to be a terribly paradoxical inconsistency of language. Let us suppose, for convenience, that no musician had what we call "absolute pitch." Under these conditions, play a tune to a musician. Now play the tune again in another key. I ask you which was the right tune. You would have to answer me that there is no meaning to one being right and the other wrong, both are equally right. Suppose I asked you which was the right pitch for the tune, and suppose you had no basis of finding out except from the tune itself. Since both tunes would be to you exactly alike, all that you would be able to say would be that they were in different keys, but you could not say which was the right key, and in fact, could not give any meaning to the word "right." Now, it is true that musicians do have absolute pitch, but that will not destroy my analogy. In that analogy, pitch shall be analogous to velocity through space. The tune to which I referred shall be analogous to an experiment which we do. The totality of all possible tunes shall be analogous to the totality of all possible experiments. The fact that there can be, in different keys, two similar tunes which sound exactly alike shall be analogous to what the principles of relativity maintain to the effect that, for every experiment performed in one system there can be another performed in another system moving with constant relative velocity, the two experiments giving results which, to their respective observers, are exactly alike. Just as from the tunes under the conditions cited you could not attach a meaning to absolute pitch, so, from the interpretations of the experiments in the other example, we find we cannot give a meaning to absolute velocity.

Earlier in this address I introduced you to our sad professor of English who was in possession of a word from which we had taken the meaning; and we promised to give him a meaning for his poor word. And so I tell you that the things which I shall call real are the principles which, in the ultimate analysis of things, are found to have the properties of harmonizing the phenomena of the universe as our senses reveal those phenomena to us. And if our professor asks for something more substantial through which the principles may operate, if he must think of things rather than of ideas, I must beg of him to remove from his consciousness the desire for the vague thing he calls substance, and I must ask him to think of the atom more as I have envisioned it a little while ago, as a goddess with rules of conduct and procedure. I must ask him to believe that the part of his desired picture which is concerned with his intuitive thoughts of reality, and to which, in illusion, he has attributed the atom's potentialities, is just the part which, in the last analysis, has no meaning as applied to the goddess. It is an idol, and our beloved professor who has worshipped it is a heathen.

Throughout the world's history man has concerned himself with seeking the explanations of things in terms of intangible deities whose decrees were the beginnings of things, and which themselves called for no reason for their origin. Man was content to begin with the decrees of the gods. And now again today, the man of science must return as to the gods; but, no longer are these gods capricious beings with attributes founded upon a supposed likeness to himself. The man of science today learns the habits of his gods by the old biblical in-

struction as applied to other beings: "By their fruits shall ye know them." He seeks to find what the gods must be that they may do that which they do.

In ancient times, and even today, there were many different concepts of the gods, all designed ultimately to fill the same rôle. And so in science today, while we are content if we find one set of principles which harmonize the universe, we have no absolute guarantee that there may not be more than one set which harmonizes it equally well. There may be many sets of gods which may be regarded as governing nature; and, I should like to us the word "real" for whom our professor of English is seeking a job, to describe equally well any one of these sets of principles, any one of these groups of gods. You can have whichever group you wish. They are all real. They are like different instructors whom you call in to tell you the story of some particular art or branch of learning. They all tell the same ultimate story, but in different ways. And if you object to my calling all of these groups of gods real, and say that only one of them can be, in actuality, real, I will bow to your desire in part. I will claim for them that as far as anything concerned with them can ever be found out, they all have the characteristics which you somehow feel can be the characteristics of only one set of them; and so I will cater to your desires to the extent of calling them all "realistic."

I shall in fact regard as real that set of principles which fits the facts. If there is more than one set, I shall be undisturbed. Even you who do not like the use of the word "real" for all of these sets of principles, will probably be more content with the designation "realistic"; and, we will make that word our starting point, and we will suggest for our professor of English a definition of the word "real" to the effect that it is a special form of the word "realistic" applicable when there is only one candidate for the designation.

In spite of all I have said, you may maintain that you cannot escape the very emphatic consciousness of the substance of things. You will tell me that when you bang your head against the wall, it seems most emphatically evident that there is reality in the wall and that the wall is there. You will protest that all things are not shadows. You will tell me that you can touch things, you can feel things, and that deep down in your very bones you believe that they are there. I sympathize with your feelings, but I must warn you that all you have as your criterion for the existence of whatever it may be that you are thinking about, all you have for your criterion of the reality of this "substance" is the set of impressions you get from your senses; and, my goddesses of the atoms, those principles which I have said are the things ultimately real will, if they have been properly chosen, reincarnate in the approximate and crude form of your senses that concept of reality with which you started, and which seemed so very substantial and meaningful to you. They will construct this reality, not with simplicity, but with the appropriate complexity which should adorn it. I fear there will be many things about it of which you will feel rather ashamed; but, humbled in its reincarnation, it will nevertheless be surer of the ground left to it. When the goddesses have reconstructed for you the meaning of the reality of my presence here this evening, you will not be so disturbed when

(*Please turn to page 63*)

PRESENT STATUS OF DENTAL RESEARCH*

J. L. T. APPLETON

The strength and influence of the Society of the Sigma Xi cannot be referred to any single cause. A va iety of factors are operative. We are interested in one another's work because (*i.a.*) no science is sufficient unto itself. We are all members, one of another. The facts, theories, and technics of other sciences are indispensable for the understanding and development of our own science, whatever that may be. In periods of healthy growth there has always been a give-and-take among the several sciences. Pasteur, the chemist and physicist, becomes the founder of bacteriology. Mayer, the physician, enunciates the mechanical equivalence of heat. Helmholz, the physiologist, becomes the physicist. Pfeffer, the botanist, arouses interest in the phenomenon of osmosis. Today, the general internist is a physiologist; and the physiologist is a chemist and a physicist; and the physicist is a mathematician—conversing (like the old New England aristocracy) on equal terms and in his own language with the deity (or at least so would Jeans and Eddington have us believe).

In brief, as scientists we are drawn together—in part—for what we can get from the other fellow. Besides this utilitarian motive, we all have one thing in common, which is our distinguishing mark: and this one thing is the intellectual method which we apply to the solution of our problems. Whether the subject matter of our field of interest falls in the physical, the biologic, or the social sciences, we apply to this subject matter the scientific method. Our common faith (our *pragmatic* faith) in the efficacy of this method is the bond which holds us tightly together as members of this Society.

* * *

Now dentistry is not a science, no more than medicine is a science. Among the jobs of dentistry is its obligation that the health of the body shall not suffer from disease of the mouth: or (to put it positively) the mouth and its associated parts shall be in such a state that they shall contribute their full share toward the health of the body.

This is not the time or place to argue the social significance of what dentistry undertakes to perform or of what it is potentially capable of performing. You may, however, permit me to introduce the testimony of two witnesses. Sir William Osler (who, you remember, was Professor of Clinical Medicine here at Pennsylvania) expressed the opinion that more physical deterioration is produced by defective teeth than by alcohol (Cushing's *Life of Sir William Osler*, 1925, 2.24). The second witness is a more recent one. In 1934 Hooton (Professor of Anthropology, Harvard) published a paper on apes, men and teeth (*Scientific Monthly*, 38:24-34), reprinted in *Apes, Men and Morons*. The following quotation indicates the tenor of his views. "I firmly believe that the health of humanity is at stake, and that, unless steps are taken to discover pre-

* Address before the Pennsylvania Chapter at the Thomas W. Evans Museum and Dental Institute, School of Dentistry, University of Pennsylvania, Philadelphia, Pa.

ventives of tooth infection and correctives of dental deformities, the course of human evolution will lead downward to extinction."

The opinions of Osler and of Hooton are called to your attention with no comment except that neither of them is a dentist and that such distinctions and emoluments as they have received, have not been gained by broadcasting the virtues of a tooth-paste or a mouth-wash.

Disease of the teeth and adjacent parts, though probably increasing, is not something particularly new in the history of the race. The shortest poem in the English language bears the title: Lines on the Antiquity of Microbes: and the poem itself is—

"Adam
Had 'em."

It might well have been entitled—Lines on the Antiquity of Molars. There is no account, canonical or apochyphal, of Adam's molars—but we do know that with the loss of innocence and Eden, death and decay came into the world; and doubtless that includes the decay of teeth and the death of the pulp. The early Semitic peoples took an esthetic and ethical delight in making the punishment fit the crime; and what could be more appropriate than that man should lose his teeth in retribution for a dietary indiscretion?

This is not all persiflage. According to Hooton, nearly all the teeth of Rhodesian man were "attacked by caries or decay; there were abscesses at the roots of many, and the 'danger-line' was riddled with pyorrhea—in fact, he sorely needed a dentist."

The problems of dental disease or the problems occasioned by dental disease have received the attention of many individuals for generations back. I shall not start earlier than with the case of John Hunter, recently characterized as "the greatest of experimental biologists." (Krumbhaar, *Pathology,* 1937, p. 110, Hoeber, New York City.) In 1771 appeared Hunter's "Natural History of the Human Teeth," a work which still repays study, and which because of its freshness and directness is a delight to read. A few years after Hunter, Benjamin Rush—whose rôle in medicine in Philadelphia and in our own medical school is well known—clearly recognized that infections around the teeth may result in serious damage to remote parts of the body, *i.e.,* he was one of the first to call attention to what is known today as focal infection. Many years after Rush, there was graduated from this dental school W. D. Miller, a true ornament to any profession or science. He is best known today because he was the first to study systematically and comprehensively the bacteria of the mouth and their relation to disease in the mouth and elsewhere in the body. There is one more personality who should not be neglected on this occasion, E. D. Cope—a Professor of Zoology at Pennsylvania and one of the titans of American paleontology—formulated a theory of the evolution of the mammalian teeth. This theory—modified by Osborn and later by Gregory—still holds the dominant position in this field.

* * *

The objective of dentistry is a biological objective—*viz.,* health and optimum function of the mouth in relation to the health and optimum function of the body

as a whole. To achieve this objective we sometimes make use of mechanical appliances and principles, which in turn require the employment of certain materials, *e.g.*, alloys, amalgams, cements, porcelains, etc. Thus, we are faced with a heterogeneous group of problems: biological, chemical, and physical: and to attack them, we draw upon the spiritual and material resources of the corresponding basic, pure sciences.

Dentistry stands as an expectant beneficiary to gain by the advances in these basic sciences. Any advance in the theory or technic of roentgenology; in endocrinology; in food or enzyme chemistry; in chemotherapy; in anesthesia; in the biology of neoplasms, of bone, of the capillaries, of the nerve cell, of muscle; in our understanding of infection, or inflammation or of allergy; in metallurgy; any advance—to mention only what comes tumbling into consciousness—is potentially applicable to dentistry. For example among the applications of the more recent methods we find that the development of the tooth and the histogenesis of its tissues are being studied (a) by transplanation, (b) by *in vitro* cultivation, (c) by the technic of incineration, and (d) by the use of radio-active phosphorus (which permits one to follow the exchange of P in the teeth under various conditions). The methods of micro-chemistry permit a direct study of the changes occurring in the isolated lesion of dental caries: the satisfaction of a need that has long been felt. The capillaroscope is being applied to the study of the circulation in the gums and lips in health and disease, and the ultracentrifuge could be used with advantage in the study of saliva.

The physical and chemical properties of dental materials are being actively studied—chiefly by the manufacturers of dental supplies. The Bureau of Standards at Washington and the British National Physical Laboratory are also engaged in this field. A number of university dental schools—including our own—cooperate with the Bureau of Standards in conducting clinical tests.

A basic, if not *the* basic, problem peculiar to dentistry is that of occlusion. By this is meant the relation of the teeth to each other, in function as well as in rest. The occlusion of the teeth influences mastication, speech, the growth of the face, susceptibility to dental decay, and the health of the tissues supporting the teeth in the jaws. Most of the work of the dentist—the filling of teeth, the making of crowns, bridges, and artificial dentures—is concerned directly with occlusion. The difficulties which arise in the performance of this work, are constant starting points for investigations: the methods and materials for taking impressions; the technics of casting; taking and recording and reproducing the "bite"; materials for dentures; the structure and function of the temporomandibular articulation; *etc.*

Besides these problems of replacement and restoration, dentistry has a number of peculiar and importunate problems which fall in the field of pathology.

They concern:

1. Diseases of the tooth, especially dental caries (decay).
2. Diseases of the tissues supporting the teeth in the jaw ("pyorrhea"), and
3. Irregularities in the position, alignment, and occlusion of the teeth (malocclusion).

These conditions have occasioned, directly or indirectly, a multitude of studies, *e.g.*, the chemistry, physical characteristics, and structure, microscopic and submicroscopic, of the dental tissues; their histogenesis; the mechanism of calcification; the chemistry and properties of saliva; blood chemistry; the influence of endocrin products and of dietary or nutritional factors; metabolic studies; hereditary or genetic, geographic, and climatic factors; the collection and analysis of anthropometric, particularly cephalometric, data.

Another important group of studies centers about the interrelations between oral diseases (particularly, oral infections) and extra-oral or general disease. In this group belong the medico-dental problems of focal infection, of syphilis, of the exanthemata, of tuberculosis and of other forms of respiratory disease, of the blood dyscrasias, of the avitaminoses, or diabetes mellitus, etc. The concept of local infection has brought to light a multitude of diverse problems, *e.g.*, the determination of the indications and contra-indications for tooth extraction; the conservation of the dental pulp, the management of pulpless teeth.

The picture of dental research as I've drawn it so far, represents only a partial truth and might easily lead to misunderstanding. Dental research is by no means as regimented by the exigencies of practice as I may have given you to believe. Though doubtless many investigations are initiated to answer a definite clinical problem, this motivation is by no means the one solely effective. Many researches are today undertaken in the spirit of pure science, with no thought of an immediate and obvious application of their results to the practice of dentistry.

* * *

A number of public-spirited individuals have established dental clinics for the care of the poor. From its beginning, the Forsyth Clinic in Boston has conducted research, concentrating first in the field of oral bacteriology and later on the influence of diet on the formation and structure of the teeth and on the etiology of dental decay. The Zoller Clinic of the University of Chicago is of too recent an origin to judge it by its fruits—but dental research is already in progress there and its program is ambitious. Its financial resources, its affiliations, and its administration hold out bright promise for the future.

Some of the large philanthropic foundations have made material contributions toward the support of dental research, *e.g.*, the Carnegie Corporation, the Rockefeller Foundation, the Commonwealth Fund, the Couzens Fund and the Markle Foundation. Possibly the most significant grants of this sort have been made, first by the Rockefeller Foundation and later by the Carnegie Corporation, to Yale University and to the University of Rochester. At these institutions have been established a number of fellowships to enable recent graduates of dental schools to obtain further training in the basic sciences and in the study of medico-dental relationships. For many years, contributions to dental research, especially in the field of focal infection, have come from the Mayo Clinic, Rochester, Minn. The United States Public Health Service is fostering dental research, especially in the field of dental caries and in a peculiar condition of the teeth, endemic in certain geographic areas, and associated with the fluorin content of the water supply, known as "mottled enamel."

Organizations and vehicles for publication are important aides to research. The International Association for Dental Research was founded in 1920. At present it consists of something over 400 members, distributed in twenty-eight sections, nineteen of which are in the United States. The others are in Vienna, Halifax, Toronto, Winnepeg, Chegtu (China), Prag, London, Budapest, and Johannesburg (South Africa). Its official organ is the *Journal of Dental Research*, now in its seventeenth volume.

CONCLUSION

No one is more keenly aware than I am, of the defects of this account of the present status of dental research. I hope, however, that I have conveyed to you the impression that it is in a state of wholesome activity. In spite of limited resources, forward steps are really being taken. The significance of the results is not yet easy to evaluate or to interpret. The future will take care of that. Those of us who can look back over twenty, thirty, or fifty odd years do feel gratified and encouraged. Oral disease is better understood, in respect both to its etiology and to its signficance; its control is more practicable and more effective; and there has been a material and widespread improvement in the health of the mouth and of the body. By utilizing the technics, facts and theories of the basic, pure sciences—by exploring more widely and more deeply the interrelations between the mouth and the rest of the body—and by patiently applying and re-applying the method of scientific research—dentistry may, perhaps, postpone for a new millenia that *dies irae* of human extinction. In the meantime (and this is more to the point) dentistry will seek to add to the health, wealth and happiness of man. Whether man deserves this—but *that*, as Kipling would say, is another story.

THE CHEMISTRY OF THE TUBERCLE BACILLUS AND RELATED ACID-FAST BACTERIA*

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During the past several years the Medical Research Committee of the National Tuberculosis Association has sponsored a comprehensive cooperative investigation on tuberculosis. The investigation has been based upon fundamental chemical studies on the metabolic products elaborated by the living organism cultivated on a synthetic medium. The chemical approach was selected in order that definite chemical fractions, such as phosphatides, fats, waxes, proteins, and carbohydrates, might be tested individually for physiological reactions or biological activity in normal as well as tuberculous animals. Furthermore purified chemical compounds such as various fatty acids, pigment, alcohols, and other cleavage products obtained in the chemical analysis of the several fractions have been studied by biological methods.

Up to the present time the investigations have dealt primarily with the carbohydrates, proteins, and fats. The specific carbohydrates or polysaccharides have been studied by Dr. Michael Heidelberger while the proteins have been investigated by Dr. Esmond R. Long and Dr. F. B. Seibert. The fats or lipids have been the object of investigations at Yale University by the writer and his students. Physiological investigations on the numerous chemical compounds which have been isolated have been conducted mainly by Dr. Florence R. Sabin and collaborators at the Rockefeller Institute for Medical Research.

In addition to the human type of the tubercle bacillus other strains of the acid-fast group have been included in this investigation; namely, the bovine and avian types of tubercle bacilli, the leprosy bacillus, and the non-pathogenic timothy grass bacillus. By examining several strains of pathogenic as well as non-pathogenic acid-fast bacilli by identical methods it was hoped to discover whether differences in specificity depended upon particular or specific chemical substances which were produced by the various organisms.

Before describing our chemical investigations of the ether-soluble fats or lipids, a brief account will be given of the methods employed in the production of bacteria on a sufficiently large scale to serve the purpose of the present work. The bacteria were cultivated under identical conditions on the long synthetic medium. This medium has the following composition:

THE LONG SYNTHETIC MEDIUM

Asparagin	5.0 gm.
Ammonium citrate	5.0 gm.
Potassium acid phosphate	3.0 gm.
Sodium carbonate	3.0 gm.
Sodium chloride	2.0 gm.

* A lecture delivered before the Yale Chapter.

Magnesium sulfate	1.0	gm.
Ferric ammonium citrate	0.05	gm
Glycerol	50.0	gm.
Water	1000.0	cc.

The only nitrogenous compounds in this medium are asparagin and ammonium salts and the main source of carbon is glycerol. The use of a synthetic medium has been considered of prime importance throughout this investigation because it guarantees that all the complex substances isolated from the bacilli must have been synthesized by the living cells from very simple chemical compounds of known constitution.

The tubercle bacillus is a microscopic living cell of rod shaped form which can be demonstrated by appropriate staining in tuberculous tissue, in the sputum of tuberculous patients, and in the colonies of bacilli growing on an artificial medium. It is the typical organism isolated by Robert Koch in 1882. The bacillus is regarded as the causative factor of tuberculosis because when it is injected into susceptible animals it always produces the disease. During recent years it has been suggested by numerous students of the tuberculosis problem that the acid-fast bacillus grown in the laboratory on artificial media is a fixed or stable form but that under different conditions of nutrition the organism may assume other forms such as cocci or granules which are non-acid-fast or even as a filterable virus. However interesting or significant such suggestions may be, the only form or manifestation of the bacillus with which we have dealt in this investigation is the rod-shaped acid-fast bacillus which grows on a synthetic medium.

The bacilli used in our experiments were grown in one litter Pyrex bottles, each bottle representing one culture, containing 200 cc. of the Long synthetic medium. During the incubation the bottles were packed horizontally in order to provide a large surface for growth because the bacilli grow only on the surface of the medium forming a faintly cream colored pellicle. The bacteria develop rather slowly requiring from six to eight weeks for maximum growth or pellicle formation. The number of cultures provided for the main experiments have varied from 1600 to 3000. The human, bovine, avian, and leprosy bacilli were supplied by the Mulford Biological Laboratories, Sharp and Dohme, while the timothy grass bacillus was supplied by Parke, Davis and Co. Without the collaboration of these commercial biological laboratories it would have been practically impossible to obtain an adequate quantity of the bacterial cells for chemical investigation.

The ether-soluble constituents or lipids of the tubercle bacillus form a very important fraction representing from 20 to 40 percent of the dried bacteria. From the standpoint of the chemist this material is an interesting mixture consisting of many different compounds such as phosphatides, fats, and waxes. The chemical investigations of these fractions have revealed a large number of new and previously unknown substances such as fatty acids, pigments, higher alcohols, carbohydrates, etc., which possess peculiar chemical and biological properties. These substances are characteristic metabolic products of the bacilli and have never been found in any other living cells.

EXTRACTION OF THE BACTERIAL LIPIDS

After the cultures had attained maximum growth the bacteria were filtered off on large Buchner funnels, washed with water, and immediately introduced into a mixture of equal parts of alcohol and ether which had been saturated with carbon dioxide. The bacteria were exhaustively extracted at room temperature first with alcohol-ether and later with chloroform. Throughout the laboratory operations air was displaced as much as possible with carbon dioxide and only carefully purified solvents were used. The extracts were concentrated under reduced pressure and at a low temperature. The alcohol-ether extracts contained fats and phosphatide together with a small amount of wax. The chloroform extracts on concentration to dryness yielded the crude wax in the form of a yellow brittle solid.

Although the bacterial residues after the above mentioned extractions were found to be free of lipids soluble in neutral solvents, yet they contained a large amount of lipid material which was firmly bound in the cellular structure. The firmly found lipids can be obtained by treating the bacterial residue with a mixture of alcohol and ether containing one percent of hydrochloric acid followed by extraction with ether or chloroform.

FRACTIONATION OF THE LIPIDS

The phosphatide was separated from the fat and other ether-soluble constituents by precipitation with acetone and was finally obtained as a white powder which dispersed readily in water-forming colloidal solutions. The material soluble in ice cold acetone was obtained on evaporation of the solvent as a reddish soft fat-like mass and was designated acetone-soluble fat.

The crude wax was purified by precipitation from ether solution with acetone or methyl alcohol until a white amorphous powder was obtained which was designated purified wax. From the mother liquors a second fraction was obtained which was of a soft salve-like consistency and was called soft wax.

The preliminary separation of the lipids into a number of more or less homogeneous primary fractions as mentioned above served a useful purpose in that a series of distinctly different products were obtained which differed in properties and in chemical composition. While none of the primary fractions can be considered as chemically pure substances, yet the subsequent analyses showed that the separation of the various types of compounds had been rather complete, *i.e.*, the phosphatides were free from fat and wax and the fats were free from phosphatide and wax.

After the preliminary separation of the lipids had been accomplished the several primary fractions were subjected to systematic studies by physiological and chemical methods. The biological reactions were studied in Dr. Sabin's laboratory. In the chemical analyses the primary fractions were hydrolyzed or saponified and the cleavage products were separated as nearly quantitatively as possible. Every substance that was isolated was purified and every new substance that was found was again submitted for biological testing. It was hoped that such systematic studies employing physiological and chemical methods

would lead to the recognition of the active principles which are responsible for some of the pathological manifestations in tuberculosis.

A summary of the several crude lipid fractions isolated from the organisms included in this study is presented in Table I.

TABLE I

PRIMARY LIPID FRACTIONS ISOLATED FROM ACID-FAST BACTERIA

Type of bacilli	Human H-37		Avian		Bovine		Leprosy		Timoth	
No. of cultures	2000		2000		1700		3000		160	
	gm.	%	gm.	%	gm.	%	gm.	%	gm.	[illegible]
Phosphatide	253.1	6.54	79.7	2.26	60.5	1.55	100.5	2.20	18.7	[illegible]
Fat	240.0	6.20	77.3	2.19	131.7	3.34	289.5	6.47	87.4	[illegible]
Crude wax	427.0	11.03	379.5	10.79	336.0	8.52	444.8	9.98	158.4	[illegible]
Total lipids	920.1	23.78	538.5	15.26	528.2	13.40	834.6	18.7	264.5	[illegible]
Bacillary residue	2902.0	75.01	2942.7	83.71	3370.1	85.50	3389.8	80.38	2783.1	[illegible]
Weight of bacteria per culture	1.928		1.757		2.318		1.488		1.982	

THE BACTERIAL PHOSPHATIDES

The chemical composition of the phosphatides isolated from the acid-fast bacteria differs very decidedly from that of the usual phosphatides of plant or animal origin. The ordinary type of phosphatide such as lecithin and cephalin contains about 4 percent of phosphorus and about 1.5 percent of nitrogen. On hydrolysis they yield saturated and unsaturated fatty acids, glycerophosphoric acid, and a nitrogenous base, choline in the case of lecithin and aminoethyl alcohol in the case of cephalin.

The bacterial phosphatides possess similar solubility properties to lecithin and cephalin in that they are easily soluble in ether and are precipitated from such solutions by acetone. They contain from about 2.5 to 3 percent of phosphorus but very small amounts of nitrogen, varying from a mere trace to about 1 percent. On hydrolysis the bacterial phosphatides yeild fatty acids, glycerophosphoric acid, and a large amount of carbohydrate. The amount of nitrogen present is so small that we have never been able to isolate or identify the nitrogenous component.

The fatty acids consist of saturated solid acids, mainly palmitic acid, unsaturated liquid acids, mainly oleic acid, and a mixture of liquid saturated fatty acids of high molecular weight. The phosphatides from all of the various acid-fast bacteria which we have studied contain analogous liquid saturated fatty acids but the liquid saturated acid fraction derived from the human tubercle bacillus is optically active, whereas the other organisms yield optically inactive acids.

The carbohydrate component of the phosphatides is apparently the same in all bacilli which we have studied. When the phosphatides are hydrolyzed with dilute acids, the carbohydrate is also hydrolyzed with the liberation of inosite, mannose, and some other hexose presumably glucose because it gives glucosazone. On the other hand when the phosphatides are saponified with alcoholic

potassium hydroxide, the cleavage products are quite different. In this case the fatty acids are split off forming alcohol-soluble soaps and there is obtained an alcohol-insoluble carbohydrate complex which contains phosphorus. When this carbohydrate is hydrolyzed with dilute acid glycerophosphoric acid, inosite, mannose, and glucose are formed.

The bacterial phosphatides contain therefore two unique and characteristic groups of substances, (a) the liquid saturated fatty acids of high molecular weight and (b) a special type of carbohydrate or polysaccharide.

The phosphatides have great affinity for water and form colloidal solutions. It has been shown by investigations in Dr. Sabin's laboratory that the phosphatides when injected into normal animals cause proliferation of monocytes and epithelioid cells resulting in the formation of typical tubercular tissue. Similar cellular reactions are produced by all the lipid fractions and it has been found that the active substance causing this reaction is the optically active liquid saturated fatty acid. Owing to the peculiar chemical and biological properties of this acid it was named phthioic acid.

THE ACETONE-SOLUBLE FAT

That portion of the bacterial lipids which is soluble in ice cold acetone we have termed acetone-soluble fat. This material is obtained as a soft or semi-solid reddish mass which possesses in a high degree the perfume-like odor of the bacterial cultures. The material is a mixture of free fatty acids and neutral fat. The neutral fat differs from ordinary fats in that it is not a glyceride but represents complex esters of fatty acids with the disaccharide trehalose.

The fat contains in addition to a number of ordinary fatty acids liquid saturated fatty acids similar or analogous to those found in the phosphatide. In studying this fraction it has been possible to separate it into three new acids by fractionation of the methyl esters: (1) tuberculostearic acid, (2) phthioic acid, and (3) a levorotatory acid.

Tuberculostearic acid is optically and biologically inactive. At ordinary temperature it is a mobile colorless oil which melts at 10-11°. It has the formula $C_{19}H_{38}O_2$ and has been shown to be 10-methyl stearic acid as indicated in the formula

$$CH_3(CH_2)_7\underset{\displaystyle CH_3}{\underset{|}{C}}H(CH_2)_8COOH.$$

PHTHIOIC ACID

Phthioic acid has the formula $C_{26}H_{52}O_2$. It melts at 20-21° and at ordinary temperature is a thick colorless and odorless oil. It is dextrorotatory with a specific rotation of +12.56°. Phthioic acid is evidently a branched chain acid but its constitution is unknown. It appears to be the biologically active component of the fat and causes on injection proliferation of monocytes and epithelioid cells and formation of tubercular tissue.

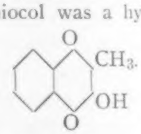
The *levorotatory acid* has not been obtained in a definitely pure state. The purest material obtained had a levorotation of -6.1° and in composition corresponded to the formula $C_{30}H_{60}O_2$. At ordinary temperature it is a white

solid which melted about 48°. It is extremely soluble in the usual organic solvents and has not been obtained in crystalline form.

These peculiar liquid acids, although they are saturated compounds, form lead salts which are very soluble in ether. In applying the lead soap-ether separation to the total fatty acids obtained on saponifying the fats the liquid saturated fatty acids appear in the unsaturated acid fraction but this mixture cannot be separated by any of the usual methods. However, by reducing the unsaturated acids catalytically with hydrogen in the presence of platinum oxide they are converted to solid saturated acids, mainly stearic acid, which can be removed by repeating the lead soap-ether treatment. In this manner the liquid saturated fatty acids have been isolated and further separated by fractionation of their methyl esters. Other new acids than those mentioned above are undoubtedly present in this mixture but so far we have not been able to separate or to purify them.

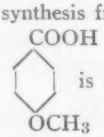
AROMATIC CONSTITUENTS OF THE ACETONE-SOLUBLE FAT

Practically all of the bacterial pigment becomes concentrated in the acetone-soluble fat which as previously stated is of dark red color. The coloration is due to the presence of a pigment whose salts with bases are bright red in color. Although the pigment is present in very small amount we were able to isolate it in pure crystalline form and to determine its chemical constitution. The substance which received the name phthiocol has the formula $C_{11}H_8O_3$. It crystallizes in fine yellow prisms and melts at 173-174°. Phthiocol on acetylation gives a monoacetate of yellow color and on reductive acetylation a colorless triacetyl derivative, while on oxidation phthalic acid is produced. From a consideration of these reactions it was evident that phthiocol was a hydroxy methyl naphthoquinone having the following constitution



This constitutional formula was confirmed by synthesis from methyl naphthalene.

Anisic Acid, p-methoxybenzoic acid



is another aromatic constituent of the acetone-soluble fat.

IDENTIFICATION OF TREHALOSE IN THE ACETONE-SOLUBLE FAT

In examining the water-soluble cleavage products of the acetone-soluble fat we have never been able to isolate any glycerol. The only water-soluble substance that we have been able to isolate and identify is the disaccharide trehalose, $C_{12}H_{22}O_{11}$, which we isolated in crystalline form from the saponification mixture of the fat from the human tubercle bacillus and also from the leprosy bacillus.

It seems rather remarkable that the acid-fast bacteria growing on a medium containing glycerol as the chief source of carbon first synthesize a disaccharide such as trehalose with which the fatty acids are combined to form the neutral fat.

BACTERIAL WAXES

Quantitatively the so-called bacterial waxes are very important because they make up the bulk of the ether-soluble constituents of the acid-fast bacteria. These substances have been called waxes because in the crude state they have properties similar to those of some waxes but in a chemical sense they are not waxes but represent esters of higher hydroxy fatty acids with carbohydrates and with certain higher alcohols.

The hydroxy fatty acids present in the waxes have very high molecular weights, from about 600 to about 1400. They are difficult to purify because they do not crystallize—hence their constitutions are unknown. These acids are nearly all optically active and they are acid-fast. In fact the hydroxy wax acids are the only acid-fast compounds that we have found and they are probably responsible for the acid-fastness of the bacilli.

THE HIGHER ALCOHOLS

All of the acid-fast bacterial waxes which we have examined contain in addition to the ether-soluble fatty acids also about 10 to 12 percent of ether-soluble higher alcohols. These alcohols are apparently specific metabolic products of the bacilli since they have never been found elsewhere in nature.

The wax from the timothy bacillus, the leprosy bacillus, and the avian tubercle bacillus contains two crystalline optically active alcohols which have the following formulas, melting points, and rotations:

$$C_{20}H_{42}O\text{, m.p. } 62\text{-}63°\text{, } [\alpha]D \text{ in } CHCl_3 +4.2°$$
$$C_{18}H_{38}O\text{, m.p. } 56° \ [\alpha]D \text{ in } CHCl_3 +5.7°$$

Both alcohols on oxidation with chromic acid are converted into crystalline ketones, thus indicating that both substances are secondary alcohols. The ketones were identified as 2-eicosanone and 2-octadecanone. The constitutions of the two alcohols were therefore established, namely as *d*-eicosanol-2, $CH_3(CH_2)_{17}CHOH \cdot CH_3$ and *d*-octadecanol-2, $CH_3(CH_2)_{15}CHOH \cdot CH_3$.

These alcohols have not been found in the wax from the human tubercle bacillus or in the wax of the bovine type of tubercle bacillus.

The wax from the human tubercle bacillus contains a new and previously unknown higher saturated alcohol which received the name phthiocerol. Phthiocerol is a colorless crystalline substance, the composition corresponding to a formula $C_{35}H_{74}O_3$, m.p. 73-74°, $[\alpha]_D$ in $CHCl_3$ -4.8°. The constitution of phthiocerol has not yet been elucidated but we have determined that it contains two hydroxyl groups and one methoxyl group.

More recently in the examination of the wax from the bovine tubercle bacillus we have found that phthiocerol is one of the components of this wax also.

THE CARBOHYDRATES FROM THE BACTERIAL WAXES

The water-soluble products obtained from the bacterial waxes on saponification vary decidedly with the type of bacteria. The wax from the timothy bacillus was found to contain both glycerol and the disaccharide trehalose. A purified wax fraction called leprosin isolated from the leprosy bacillus contained only glycerol. The avian tubercle bacillus wax contained only trehalose. The wax from the bovine tubercle bacillus contained a polysaccharide essentially similar to the carbohydrate fraction of the phosphatide of the human tubercle bacillus. The crude wax isolated from the human tubercle bacillus could be separated into two fractions. One fraction was a soft solid at room temperature while the principal fraction was a white powder which melted with decomposition at 200-205°. The soft fraction of the wax yielded glycerol as the only water-soluble material on saponification. The high melting fraction which was termed purified wax gave nearly 40 percent of a new and specific polysaccharide which gave a precipitin reaction with immune serum in dilutions up to 1:1,000,000. The polysaccharide differed entirely in composition from all of the other carbohydrates encountered in our analyses of bacterial waxes. After hydrolysis with dilute acid the cleavage products were found to consist of *d*-mannose, *d*-arabinose, and *d*-galactose together with traces of inosite and glucosamine.

The results of our analyses of the carbohydrates of the waxes from acid-fast bacteria indicate clearly that the wax from the human tubercle bacillus is quite different in its carbohydrate component from many other bacterial wax. In fact, the nature of the cleavage products of the polysaccharide could serve as an excellent means of differentiating the human type of tubercle bacilli from all other types of acid-fast bacteria.

The composition of the wax from the bovine tubercle bacillus is also distinctly different from the other bacterial waxes but the carbohydrate as well as phthiocerol would indicate that there is a closer relation between the bovine and human tubercle bacilli than between the other members of the acid-fast group of bacteria.

FIRMLY BOUND LIPIDS

When the acid-fast bacteria are exhaustively extracted with neutral solvents such as alcohol, ether, or chloroform, there always remains a large proportion of lipid material in the cells which cannot be removed. However, if the bacterial residue is treated with dilute acid, the residual lipid material can be easily removed by extraction with ether or chloroform. The crude lipid fraction represents a complex mixture but the principal component is a substance of very high molecular weight. It is very readily soluble in ether or chloroform but these solutions cannot be filtered through a Chamberland filter. In attempting to filter such solutions under pressure, it was found that only the solvents passed through the filter. When the product is purified by precipitation from ethereal solution by addition of alcohol, a white amorphous powder is obtained which when heated melts with decomposition at about 200°. On saponification the unfilterable lipid yields about equal parts of ether-soluble and water-soluble

components. The ether-soluble fraction consists almost entirely of a hydroxy fatty acid, m.p. 56-57°, with a molecular weight of about 1200. This acid appears to be identical with the similar acid present in the purified wax. The water-soluble component consists of a polysaccharide which appears to be identical with the polysaccharide obtained from the purified wax. It gives a precipitin reaction with immune serum in dilutions up to 1:1,000,000 and on hydrolysis yields *d*-mannose, *d*-arabinose, and *d*-galactose.

THE UNSAPONIFIABLE MATTER OF THE BACTERIAL FATS

The unsaponifiable matter obtained after the bacterial fats had been saponified was in every case a very dark colored plastic mass. Lack of time has prevented any exhaustive investigations of these fractions but examination for sterols has yielded practically negative results.

The lipids of the human tubercle bacillus was examined with care for the presence of sterols by means of the digitonin precipitation method but only traces of insoluble digitonides were obtained. The digitonides gave a positive Liebermann-Burchard reaction but the amounts of precipitates were so insignificant that they could only be attributed to accidental contaminations of sterols derived from corks, filter papers, etc., used during the handling of the bacterial extracts. Since sterols are found in all higher forms of life, both animals and plants including various species of moulds and yeasts, the lack of sterols in detectable quantity in tubercle bacilli and other acid-fast bacteria indicates a distinct difference in metabolism of these organisms from other living cells.

In the examination of the unsaponifiable matter of the fat from the leprosy bacillus, we isolated two interesting new higher alcohols which possessed phenolic properties. The new alcohols, named α- and β-leprosol, were identical in chemical properties and in composition and corresponded to the formula $C_{26}H_{46}O_2$. Both substances contain one hydroxyl group which is phenolic in character and one methoxyl group. The leprosols form insoluble digitonides but they give no sterol color reactions. The functions and biological reactions of these alcohols are as yet unknown and their chemical constitutions have not been determined.

It is evident from the results that we have obtained in the investigations of the lipids of the tubercle bacillus and other acid-fast bacteria, that these organisms elaborate a large number of new and peculiar chemical compounds which are characteristic metabolic products of the acid-fast group. The composition of the phosphatides, fats, and waxes indicates a family resemblance which is in agreement with the morphological and staining properties of the bacilli. At the same time some of the strains show decided variation which sharply distinguishes them from other members of the group. The human tubercle bacillus stands out especially as containing unique and characteristic substances which we have not found in the other types. The most striking substances being optically active liquid saturated fatty acids such as phthioic acid, the specific polysaccharide present in the wax fraction, and the dihydric alcohol phthiocerol.

The results reported in this review have been published in a series of papers in the *Journal of Biological Chemistry*, *Z. physiol. Chem.*, *Journal of the American Chemical Society*, and in *Physiological Reviews*.

MINUTES OF THE MEETING OF THE EXECUTIVE COMMITTEE OF SIGMA XI, RICHMOND, VIRGINIA, DECEMBER 28, 1938

The second meeting of the Executive Committee for 1938 was held in the Jefferson Room of the Hotel Jefferson, Richmond, Virginia, December 28, 1938, at 12.00 M. Present were: President Baitsell, Secretary Ellery, Treasurer Pegram, Professor Stadler, Dr. Durand, Mr. Norton, and by invitation, Past-president Dr. L. B. Wilson, Mr. C. E. Davies of the Alumni Committee, Professor H. J. Creighton, chairman of the committee on Sigma Xi lectures for 1939.

Business was transacted as follows:

1. Formal Petitions for Charters for Chapters.

It was

Voted: To present to the 39th annual convention, with recommendation for favorable action, printed petitions for charters for chapters from groups of the faculty at the following institutions:

a. The University of West Virginia.
b. The University of Alabama.

2. Content of the Formal Printed Petitions for Charters for Chapters.

The present formal petitions for charters for chapters contain a list of university or college publications, a letter of endorsement from administrative officers, the names, academic positions and personal records of the signers. A number of chapters have given expression to their desire for somewhat detailed information regarding the resources and equipment of the institution, research in progress, scientific papers published by members of the faculty—information which the Executive Committee has had in its possession and has studied before the petition goes to the chapters and comes to the convention. Chapters have further pointed out that the vote of the convention on the petitions for a charter for a chapter has, in reality, been a vote to accept (or reject) the recommendation of the Executive Committee, without adequate knowledge of the basis of such recommendation. In view of all these circumstances, it was

Voted: That future formal petitions for charters for chapters shall contain in addition to their present content an abbreviated statement of the resources and equipment of the institution, an abstract of the findings of the official visitors, an account of research in progress, and a list of recent publications by members of the scientific staff.

3. Reports of Official Visitors.

Reports were received as follows:
a. Dr. Durand and Dean Pegram, the University of Southern California.
b. Mr. Davies, the Virginia Polytechnic Institute.

(A copy of each of these reports is on the permanent files of the secretary's office.)

After full discussion, it was

Voted: That further action regarding a chapter at these two institutions be postponed to the April meeting.

4. Preliminary Information about Institutions.

a. Utah State Agricultural College.

Detailed information about this institution was distributed to the committee November 2, thus affording ample opportunity for its study. After some discussion, in view of limitation of time at the disposal of the committee at this meeting, it was

Voted: That further action on the question of a possible establishment of a chapter of the society at the Utah State Agricultural College be postponed until the April meeting.

b. Oberlin College.

The secretary reported that just prior to the meeting of the committee a representative from Oberlin College had submitted detailed information about the resources, equipment, and research output of Oberlin College—too late for manifolding and distribution among the members of the committee. It was

Voted: That the secretary arrange for manifolding the information about Oberlin College and submit it to the members of the committee one month before the April meeting; and further, that a consideration of the information be made a special order of business at the April meeting.

5. Amendment to the Constitution.

The attention of the committee was directed again to the proposed amendment to the constitution which the committee at the April 1938 meeting voted to present to the convention. The committee was of the opinion that the amendment should stand as printed in the March and September issues of the Quarterly, and as announced to the chapters in September. The amendment is as follows:

"That a Section 4 be added to Article II of the present constitution, reading:

> "Article II, Section 4. The charter of an established chapter of Sigma Xi may be revoked only by a three-fourths vote of a convention following a recommendation of the Executive Committee, which recommendation has been communicated to each chapter not less than four weeks before the date of the convention."

6. The Society's Insignia.

The secretary announced that as a result of the poll taken by correspondence regarding a change in the official jeweler of the society, the L. G. Balfour Company of Attleboro, Mass., had been appointed official jeweler of Sigma Xi.

7. Reports of Officers.

a. The President's report. (*See page 66.*)

b. The Secretary's Report. (*See page 71.*)

c. The Treasurer's Report. (*See page 75.*)

Following the treasurer's report, it was

Voted: To present to the convention the following resolution with recommendation for favorable action:

Resolved: That the annual assessment on each chapter for 1939 shall be payable on January 1, 1939, and that the amount of the assessment on each chapter shall be 75c. multiplied by the number of members and associates of the chapter on January 1, 1939.

Resolved further: That in sending notice of the 1939 assessment to chapter treasurers, the treasurer of the society be instructed to advise each chapter that the assessment is to be computed strictly on the basis of the number of members and associates on the membership roll of the chapter, without regard to whether said members have or have not paid current chapter dues, and to explain that this method of fixing the amount of the assessment on each chapter has been adopted by the conventions of the society as the most equitable to all chapters.

8. Report of Committee on Policy.

Many important suggestions about the future policy of the society have not as yet been acted upon by the Executive Committee, and the time at the disposal of the Executive Committee at this December meeting did not permit of adequate consideration of the proposals. The Executive Committee was of the opinion that the recommendations of the Committee on Policy should form an important item on the agenda of the April (1939) meeting.

9. Sigma Xi Membership Structure.

The secretary quoted letters from chapters expressing dissatisfaction with the present policy of electing undergraduates as associates. Attention of the committee was also called to the practice of several chapters of limiting their elections to graduate students. The secretary read letters from chapters suggesting new classes of members to be known respectively as "honorary" and "life" members.

The Alumni Committee, through its chairman, Mr. Norton, made definite recommendations regarding the election of undergraduates to full membership.

Dr. Wilson suggested that the society might well consider at this time the recognition of noteworthy achievement in research by creating a class of members to be known as "fellows."

In view of these suggestions and recommendations, it was

Voted: That the president be authorized to appoint a committee to study the membership structure of the society and make report to the April meeting of the full committee.

10. The 1939 Lecture Series.

a. The lecturers, their topics and their itineraries are given in full in the report of the president.

b. The secretary presented a request from the Missouri Chapter to be allowed to include in a printed account of the Centennary Celebration of the University the lecture which they had invited Professor Stadler to give as a part of the Centennary program. This lecture is one of the 1939 Sigma Xi lectures, and will form a part of the volume containing all the lectures of the series which the society will publish later. In view of that latter fact, it was

Voted: That all the lectures of the Sigma Xi lecture series should be reserved exclusively for publication under the auspices of the national society; and the secretary was instructed to inform the Missouri Chapter of this stated policy of the society.

c. The committee voted by correspondence to continue the series of Sigma Xi lectures for 1940, and to authorize the president to appoint a committee on lectures.

11. Grants-in-Aid

a. The full report of the committee of award of the Sigma Xi grants-in-aid (Dr. Whitney, Professor Calkins, Professor Shapley) is given in the president's report .

b. Acting on the request of the Executive Committee at its April (1938) meeting, the secretary presented a list of the awards of the grants-in-aid for the last five years, as follows:

1933-34

Charles Ernest Braun, University of Vermont, $150. For continuance of the study of the relationship between guanidine structure and hypoglycemic activity.

Fred Wilbert Emerson, New Mexico Normal University, $60. For study of the adjustment of plants to the peculiar life conditions of the white sands near Alamogordo, New Mexico.

Edwin T. Hodge, Oregon State Agricultural College, $100. For analytical work in connection with a large suite of Oregon rocks.

C. J. Krieger, University of St. Louis, $100. For publication of a paper on "Preliminary Table of Lines in the Spectrum of Delta Cephei."

Ruth Marshall, Rockford College, $100. For continuance of work on hydracarina of Wisconsin.

T. L. Smith, College of the Ozarks, $150. For research on a species of lepidoptera-galleria mellonella L.

1934-35

H. R. DeSilva, Massachusetts State College, $100. For a study of the correlation of body voltage changes with basal metabolism by gasometric method.

Rachel Emilie Hoffstadt, University of Washington, $100 (renewal). To continue a study of the relation of the soluble specific carbohydrate of staphylococcus aureus with its variants.

I. M. Kolthoff, University of Minnesota, $300. For a study of the internal structural changes taking place in freshly formed lead sulfate.

F. C. Schmidt, Union College, $150. For apparatus and chemicals for continuance of measurements of heats of reaction in liquid ammonia.

T. L. Smith, College of the Ozarks, $150 (renewal). To continue a study of the effects of X-rays and radium emanations in producing genic changes on Galleria.

W. J. Luyten, University of Minnesota, $200. In support of studies of proper motion of faint stars.

1935-36

Leonard B. Clark, Union College, $250. For study of recovery process in amoeba after stimulation by light.

Nephi Willard Cummings, San Bernardino Valley Junior College, $100. For further calibration of the Burt phototube as a pyrheliometer; further studies with the thermally insulated evaporation pan in the hope of developing methods for obtaining automatic records; the relation between transpiration and evaporation from soil on the one hand and insolation and atmospheric conditions on the other.

Ernest E. Dale, Union College, $100. For continued study of the inheritance of variegation in Salpiglossis.

W. J. Luyten, University of Minnesota, $100 (renewal). For continuance of studies of proper motion of stars.

Frederic Cowles Schmidt, Union College, $50 (renewal). For study of heads of reaction in liquid ammonia.

Frederic A. Scott, Lehigh University, $300. For study of positron spectrum of the thorium active deposit; redetermination of endpoint of β-ray spectrum of radium E.

T. L. Smith, College of Ozarks, $100 (renewal). Continuation of the experimental work on the genetics of the wax moth, including an attempt to analyze the cause for sterility between two strains of the same species of the moths.

Duncan. Stewart, Jr., Michigan State College, $200. For continuation of a petrographical study by modern quantitative methods of rock specimens from Antarctica.

Charles Oscar Swanson and John Huntington Parker, Kansas State College, $100. For study of the inheritance of gluten strength in wheat hybrids, as determined by the wheat-meal-time fermentation test.

Everett Whiting Thatcher, Union College, $400. For study of multiple space charge. In particular, its influence on statistical fluctuations in the electron stream.

Abraham White, Yale Medical School, $100. For study of the proteolysis of proteins.

1936-37

C. W. Briggs, Dillard University, $250. For work on the biochemistry and physiology of medusae.

Tze-Tuan Chen, Yale University, $150. For work on the physical basis of heredity in unicellular organisms.

Calvin Springer Hall, Jr., University of Oregon, $200. For work on the inheritance of emotionality.

George William Hunter, 3rd, Wesleyan University, $300. For work on the reaction of host to the penetration of various parasitic worms.

Hubert M. James, Purdue University, $230. For work on wave mechanical computation of molecular forces and computation of nuclear wave functions.

Donald B. Lawrence, Johns Hopkins University, $300. For studies on the submerged forest on the Columbia River.

Donald H. Menzel, Harvard University, $150. For a rapid galvanometer to make possible high precision in the study of the spectograms on the Siberian eclipse expedition.

Joseph Valasek, University of Minnesota, $300. For completing a normal incidence vacuum spectograph in a study of absorption and fluorescence spectra of gases in the far ultra-violet.

1937-38

Alan Arthur Boyden, Rutgers University, $150. For serological study of the relationship of Crustacea.

Leopold Raymond Cerecedo, Fordham University, $250. For development of a 2-day test for the bio-assay of antineuritic concentrates in mice.

Forrest F. Cleveland and M. J. Murray, Lynchburg College, $300. For study of the Raman effect and molecular structure.

Maurice Ewing, Lehigh University, $200. For study of the geophysical investigations of oceanic basins.

George William Hunter, III, Wesleyan University, $250 (renewal). Continuation of studies of the reaction of the host to the penetration of larval parasites.

Louallen F. Miller, University of Minnesota, $250. For study of solar radiation by spherical absorber.

Edgar J. Murphy, College of the City of New York, $150. For design, construction and calibration of suitable apparatus for measurement of X-rays and Gamma rays. To make a study of the stray radiation in the vicinity of the X-ray tubes and radium packs located in the various city hospitals. Design and construction of Geiger Muller tubes for measuring high intensity radiation.

Jens Rud Nielsen, University of Oklahoma, $200. For study on Raman spectra and structure of simple polyatomic molecules.

Aaron John Sharp, University of Tennessee, $250. For study of types and distribution of certain bryophytes and spermatophytes.

c. A letter was presented from Clyde R. Miller, Secretary of the Institute for Propaganda Analysis. The object of the Institute is "to help the intelligent citizen detect and analyze propaganda." Mr. Miller asked whether the Society of the Sigma Xi would be will-

ing to use some of its grants-in-aid fund to set up a Sigma Xi scholarship in some university "for some young man or woman particularly interested in the weighing of evidence and the testing of authority in the highly complicated and controversial field of propaganda and public opinion." The committee did not take definite action on this inquiry, but the opinion of the committee was expressed as follows:

1. That this field of study is not one of the nine fields of science which the society includes in its activities;
2. That the committee of award of the Sigma Xi grants-in-aid should consider the possibility of assigning some of its funds available for grants-in-aid to institutions or to heads of science departments to be given young research workers who are at work on important projects and who in the judgment of the department heads show exceptional research ability.

12. The Sigma Xi Quarterly.

The committee on policy recommended among other suggestions that a sub-committee be appointed to consider the editorial policy of the Quarterly and to make recommendations for consideration at some future meeting of the Executive Committee. Accordingly, President Baitsell asked Dean Richtmyer to act as chairman of a committee on Quarterly and to suggest other members of the committee. Dean Richtmyer named the following as members of a committee on Quarterly: Edward Ellery, George A. Baitsell, Harold C. Urey, Watson Davis.

13. Sigma Xi Publicity. (Report given and action taken by correspondence.)

The secretary called the attention of the committee to the fact that the general public, both scientific and lay, does not know of the activities of the national society of the Sigma Xi in the promotion of scientific research-activities covering the whole country and entirely distinct from those of the individual chapters, which are more or less local; and presented correspondence on this important matter with Watson Davis, Director of Science Service, which:

1. Emphasized this lack of adequate publicity for the activities of a great and important organization;
2. Asked the society to cooperate in the work of interpreting the natural sciences to the general public; and
3. Requested that copies of the Sigma Xi lectures for 1939 be made available to Science Service ten days in advance of the date of the first lecture in each schedule for abstracting and release to the national and local press where Science Service has newspapers.

Mr. Davies offered timely comments on this important subject, suggested additions to the attractiveness of the annual Sigma Xi lecture event, and offered to help the society in getting proper publicity for our annual lecture for our prize awards when and if made, for our grants-in-aid, and for the

lecture series both at the time of their delivery and of their publication in a single volume.

1. The committee authorized the secretary to make temporary arrangements with Science Service for proper and dignified publicity in connection with the national activities of our society and

2. The president to appoint a sub-committee on publicity.

President Baitsell appointed as such committee Mr. Davies, Mr. Davis and Secretary Ellery.

14. Sigma Xi in Industrial Research Laboratories.

The secretary reported the stately installation program of the Florida Chapter. A leading and impressive part of the ceremony was a luncheon address by Professor Charles Carroll Brown, second president of Sigma Xi (1893-1895). In that address the speaker raised the question as to whether the development and expansion of Sigma Xi had reached the stage of establishing chapters in the great research laboratories of some of the industries of the country. Following the Florida installation Professor Brown submitted a definite recommendation for the consideration of the Executive Committee that Sigma Xi expand its activities by encouraging formation of chapters in such industrial laboratories.

The secretary is including this subject in the agenda of the April (1939) meeting.

15. Eligibility to Membership in Sigma Xi. (By correspondence.)

Following the action of the 1929 convention of the society, which limited the fields of science recognized by Sigma Xi, the Executive Committee in April 1930 informed all chapters that in case of doubt regarding the eligibility of investigators in these or other fields, the chapters, before election takes place, should ascertain and be guided by the opinion of the Executive Committee. Two such cases presented by correspondence were as follows:

a. University of Washington Chapter.

This is a question involving the interpretation of the term "sciences of the earth" as given in the list of sciences recognized by Sigma Xi. Are geographers, other than of the political type, eligible?

b. Wyoming Chapter.

Are animal production tests at the experiment station of this university included in the term "investigation in science pure and applied" as used in Section 2 of Article I of the national constitution?

The committee expressed judgment as follows:

a. Yes, if theses or papers submitted indicate that geological, ethnological, etc., bases are involved.

b. Yes, if nutrition or genetic studies are involved. Doubtful, if only economic problem is involved.

16. CHAPTER DUES PAID TO NATIONAL TREASURER.

The North Carolina Chapter asks, can an associate be allowed to pay lower chapter dues than those regularly levied, and not receive the QUARTERLY, and remain active in the chapter?

Voted (by correspondence), that the assessment annually levied by the convention is uniform for all members and associates enrolled in the chapters. Local chapter dues are fixed by individual chapters independent of the national convention.

17. CERTIFICATES IN COMMENDATION OF RESEARCH.

At the April (1938) meeting of the Executive Committee it was voted that, in view of the labor involved in the reading and appraising of the theses submitted in competition for the society's certificates in commendation of research, the policy of awarding such certificates be discontinued.

Professor G. W. Stewart, with whom this activity of Sigma Xi originated, expresses his regret at this action of the committee, and raises the following questions:

a. Is there any evidence that research has been, or has not been, noticeably promoted by the granting of these certificates in institutions in which there are no chapters of Sigma Xi?

b. Is there any evidence that the students participating have been benefited? Is anything known of their subsequent careers?

c. In view of the discouraging effect of the depression on research activities of less privileged institutions, is it advisable for Sigma Xi to devise some form of activity looking to the encouragement of the research workers in institutions where the society does not have chapters?

(This matter is reserved for the April (1939) meeting.)

18. THE 18TH ANNUAL LECTURE.

The following were named as possible lecturers for the 18th annual Sigma Xi lecture at the 1939 meetings of the A. A. A. S.:

Charles H. Best of Toronto.
Harold C. Urey of Columbia.
Hugh Taylor of Princeton.
Russell M. Wilder of Mayo Institute.
Herbert Clark of Gorgas Institute.
Kirtley F. Mather of Harvard.

19. THE SPRING MEETING.

The date of April 26 and Washington were suggested tentatively as the time and place of the Spring Meeting of the Executive Committee.

20. PRINTING THE CONSTITUTION.

The secretary suggested a new printing of the constitution to contain amendments adopted in 1936 and 1938.

Voted (by correspondence) that a new printing of the national constitution be authorized.

21. Mimeograph for the Secretary's Office.

The committee authorized the purchase of a mimeograph machine for the office of the secretary.

22. Adjournment.

The meeting was adjourned at 4.00 p.m.

Edward Ellery, *Secretary.*

Modern Trends in Air Transport

(*Concluded from page 18*)

The true helicopter appears finally to have made its appearance in Germany, though detailed information is lacking. With the shaft vertical in still air, this type of structure is capable of vertical ascent or descent. In moderate wind with the shaft inclined against the wind, the same results are possible. When a suitable altitude has been reached, the shaft is inclined so as to give a forward component to the pull of the propeller, and a horizontal component to the motion results. This type of structure has long been the subject of repeated effort. It is too soon to prophesy as to what place it may be able to take in the field of air transport. As with the autogyro, it does not seem likely that speeds comparable with those attainable with conventional forms can be hoped for. With development, however, and satisfactory solution of the problem of assured control in the air—a problem somewhat troublesome with both the autogyro and the helicopter—it may well take its place with the autogyro in types of service where the special characteristics of these forms meet peculiar and limiting conditions.

Air transport is the newest of those agencies whereby we move things about (ourselves included) over the face of the earth. Improved means of transport is one of the major factors leading to the profound differentiation between the physical conditions of our modern life as compared with the life of our forebears of the centuries gone by. Until 1903 our movements were, so to say, two dimensional. With the achievement of the Wright Brothers, in 1903, a third dimension was opened up. Man began to fly. And so air transport is only an infant among other and older agencies; one regarding which many problems yet remain for study and solution; but withal, an infant of lusty growth and seemingly destined to go far. The mission of air transport is to serve the public; and to render such service acceptable, continuously improving combinations must be found of the distinguishing characteristics—safety, economy, weight carrying capacity, speed and comfort. The story of the past thirty-five years gives good ground for faith in the future and that the unfolding years will indeed bring such improving combinations in full measure with advances in science and technology—advances on which all improvement in the material content of our lives must depend.

THE THIRTY-NINTH CONVENTION

The Thirty-ninth Convention of the Society of the Sigma Xi was held in the Hotel Jefferson, Richmond, Va., December 28, 1938.

1. Call to Order.

   The business session was called to order at 4.00 P.M. by the President, Professor George A. Baitsell of Yale University.

2. Committee on Credentials.

   President Baitsell announced a Committee on Credentials, as follows:

   Professor D. L. Holl, Iowa State College, Chairman.
   Professor Emmett B. Carmichael, University of Alabama.
   Professor H. Jermain Creighton, Swarthmore College.

3. Report of the Committee on Credentials.

   The Committee received the credentials of the delegates and reported that forty-seven chapters (with fifty-eight delegates) and eleven clubs (with eighteen delegates) were represented as follows:

   a. Chapters represented by delegates present and voting (the list is alphabetical not chronological):

Buffalo
California at Berkeley
Colorado
Cornell
District of Columbia
Duke
Florida
George Washington
Harvard
Indiana
Iowa
Iowa State
Johns Hopkins
Kansas
Kentucky
Lehigh
Maryland
Mayo Foundation
Michigan
Minnesota
Missouri
Nebraska
New York
North Carolina
North Dakota
North Western
Oklahoma
Oregon
Oregon State
Pennsylvania
Pennsylvania State
Pittsburg
Rensselaer
Rutgers
Stanford
Swarthmore
Syracuse
Texas
Tulane
Union
Virginia
Wellesley
Western Reserve
Yale

   b. Chapters reported as represented by delegates but not recorded as voting:

Columbia
McGill
Rochester

   c. Chapters which had named delegates but were not reported as represented:

California at Los Angeles
Case
Massachusetts State
Smith
Utah

   d. Chapters which had not reported appointment of delegates and were not reported as represented:

Arizona
Brown
California Institute of Technology
Carleton
Carnegie Institute of Technology
Chicago
Cincinnati
College of Medicine, University of Illinois
Idaho
Illinois
Kansas State
Massachusetts Institute of Technology
Michigan State
Ohio
Princeton
Purdue
Rice
State College of Washington
University of Washington
Washington University
Wesleyan
Wisconsin
Worcester
Wyoming

e. Clubs represented:

Alabama	Louisiana State	Vermont
Bucknell	Maine	Virginia Polytechnic
Emory	North Carolina State College	West Virginia
Georgia	Oklahoma A. and M.	

f. Officers present.

President Durand, Secretary Ellery, Treasurer Pegram, Professor Stadler, Dr. W. F. Durand, Harold F. Norton, C. E. Davies.

[The secretary appends to the report of the Committee on Credentials the following record of attendance at the last five conventions:

	Chapters present and voting	*Total number of chapters*	*Clubs present*	*Total number of clubs*
1933	34	62	6	31
1934	46	64	6	32
1935	52	66	12	36
1936	46	68	7	34
1937	56	72	10	34
1938	44	76	11	37]

4. MINUTES OF THE THIRTY-EIGHTH CONVENTION.

The account of the proceedings of the Thirty-eighth Convention of the Society, held in Indianapolis, Ind., December 28, 1937, as published in the March, 1938, QUARTERLY, was approved as printed.

5. REPORT OF THE PRESIDENT.

(See page 66.)

6. REPORT OF THE SECRETARY.

(See page 71.)

7. REPORT OF THE TREASURER.

(See page 75.)

8. ASSESSMENT FOR 1939.

In accordance with the usual procedure and policy of the convention, and upon the recommendation of the Executive Committee, the following resolutions were adopted:

Resolved: That the annual assessment on each chapter for 1939 shall be payable on January 1, 1939, and that the amount of the assessment on each chapter shall be 75c. multiplied by the number of members and associates of the chapter on January 1, 1939.

Resolved further: That in sending notice of the 1938 assessment to chapter treasurers, the treasurer of the Society be instructed to advise each chapter that the assessment is to be computed strictly on the basis of the number of members and associates on the membership roll of the chapter, without regard to whether said members have or have not paid current chapter dues, and to explain that this method of fixing the amount of the assessment on each chapter has been adopted by the conventions of the Society as the most equitable to all chapters.

9. Grants-in-Aid of Research. (See President's Report.)

10. Lectures for 1939. (See President's Report.)

11. Publication by the Society of a Scientific Book, "Science in Progress." (See President's Report and advertisement in this issue of the Quarterly.)

12. Amendment to the Constitution.

In accordance with previous notice to all chapters, and with statement published in the September, 1938, Quarterly, as required by the constitution in the matter of proposed amendments to the Constitution, the following amendment was presented:

> *Article II, Section 4.* The charter of an established chapter of Sigma Xi may be revoked only by a three-fourths vote of a convention following a recommendation of the Executive Committee, which recommendation has been communicated to each chapter not less than four weeks before the date of the convention.

In the discussion it was pointed out that while there is no present necessity to consider the possible recall of a charter for a chapter, the constitution made no provision for such action on the part of the National Convention should occasion arise. It was

Voted: That the amendment of the constitution as appears above be adopted.

13. The Present Membership Structure of the Society.

The delegate from the Rensselaer Chapter (Prof. Robert A. Patterson) raised a question as to the present grouping of the Society's constituency, namely associates and members, whether that policy of the Society was satisfactory to the chapters. In all the chapters established since 1922, according to the terms of the constitution, undergraduates may be elected into the Society as associates only, and most of the older chapters, with which the matter of such election is optional, have adopted the policy. A number of chapters do not elect undergraduates at all, limiting their elections to graduate students, most of whom come into the Society as members. Other delegates described the practice of their chapters, and all who spoke were of the opinion that the time had come for the Society to look into the whole matter of its membership structure.

It was

Voted: That the President be authorized to appoint a committee to study the membership structure of the Society for report at some future convention.

14. Petitions for Charters for Chapters.

Formal printed petitions for charters for chapters at the University of West Virginia and the University of Alabama were presented to the convention by the Executive Committee, with recommendation for favorable

action. These petitions had been distributed to the chapters early in November.

a. University of West Virginia.

It was

Voted: That the petition be granted.

b. University of Alabama.

It was

Voted: That the petition be granted.

15. Election of Officers.

The Committee on Nominations was as follows:

Professor Ralph W. Chaney, California at Berkeley, Chairman.
President Karl Compton, Massachusetts Institute of Technology.
Professor P. H. Mitchell, Brown.

The following officers were proposed:

Member of the Executive Committee:

Professor Carl D. Anderson, California Institute of Technology.

Member of the Alumni Committee:

Dr. Florence Sabin, Rockefeller Medical Institute.

It was

Voted: To instruct the Secretary to cast one ballot for each officer as named.

President Baitsell declared each officer duly elected, after the Secretary had announced that the ballot had been cast.

16. The 17th Annual Sigma Xi Lecture.

President Baitsell announced that the 17th annual Sigma Xi lecture would be given by Dr. W. F. Durand at 8.15 P.M. at The Mosque, on the topic, "Modern Trends in Air Transport."

17. Adjournment.

The 39th Convention adjourned at 5.40 P.M.

Edward Ellery, *Secretary.*

Carl D. Anderson

Carl D. Anderson

CARL DAVID ANDERSON

The newly elected member of the Executive Committee of the Society of the Sigma Xi, Carl David Anderson, was born in New York City in 1905. He holds the degrees of B.S. (1927) and Ph.D (1930) from the California Institute of Technology, and the degree of Sc.D. (honorary, 1937) from Colgate University. He has been successively Assistant and Teaching Fellow in Physics, Research Fellow, Assistant Professor and Associate Professor at the California Institute of Technology, and has been awarded the gold medal of the American Institute of New York City (1935), The Nobel Prize (1936), and the Elliott Cresson Medal of the Franklin Institute (1937). He is a member of the National Academy of Science and the American Philosophical Society, and is a Sigma Xi National Lecturer during the current year.

What Has Become of Reality in Modern Physics?

(*Concluded from page 33*)

confronted with the alarming doubts which I cast upon this matter at the beginning of my address and concerned with the fact that your evidence as to the presence of what you call this three-dimensional being who is addressing you came through two-dimensional images upon the retinas of your eyes, images which occurred twice, once in each eye, images which were upside down, and which conveyed their message to your thoughts by a process in which what the right eye sees the left-hand side of the brain interprets.

And so we begin to see that, in line with the spirit of this philosophy, there is an artificiality in the old reality, and a true reality in the new artificiality. The new reality is not a development or an enhancement of the principles of the old; but, the old is rather a rickety, somewhat illogical, vague, and incomplete structure which comes nearest to respectable form when reincarnated out of the principles of the new.

If, in spite of all I have said, you still seek to prune your own concepts into something which, over the whole realm of nature, has those elements of reality desired by your primitive senses, then I fear you are doomed to disappointment. At best, you are doomed to the life of one who seeks an ideal which becomes more and more remote as he continues to pursue it. Like the moon, the ideal will always seem to lie behind the mountain ahead; or, like the rainbow which seems to descend to the earth at some definite spot, it will move away from you as you approach the spot where it seemed to be. It is said that God fashioned man in His own image; but, it is very evident that it is man who has fashioned God in his image. If, in your search for that which the imp in your soul has told you is final and which is reality, you should beguile some sorcerer to bring your ideal to you for a moment for your inspection, you will see but the image of your own face in the picture. You will see the mechanism of that thing which was the old reality fighting like an octopus to find holds for its tentacles upon the true realities of nature; and, as you examine more closely the form and actions of that octopus you will find that it is none other than your own brain.

"SCIENCE IN PROGRESS"

TEN RECOGNIZED LEADERS IN THE PHYSICAL AND BIOLOGICAL SCIENCES HERE DESCRIBE THE METHODS EMPLOYED AND THE RESULTS OBTAINED FROM BASICALLY IMPORTANT RESEARCHES WHICH HAVE RECENTLY ENGAGED THEIR ATTENTION. PARTICULAR ATTENTION IS GIVEN TO THE RELATIONSHIPS BETWEEN THE NEWLY ACQUIRED KNOWLEDGE AND THAT PREVIOUSLY EXISTING. THE LAST FEW YEARS HAVE BEEN MARKED BY UNUSUALLY IMPORTANT ADVANCES IN VARIOUS SCIENTIFIC FIELDS, BUT COMPARATIVELY LITTLE INFORMATION HAS BEEN AVAILABLE RELATIVE TO THESE NEWLY PLACED MILESTONES EXCEPT TO THE ACTIVE WORKERS THEMSELVES. THE DISCOVERIES ARE WELL-ESTABLISHED AND OF SUCH BASIC IMPORTANCE AS TO MAKE IT ESSENTIAL TO HAVE THE INFORMATION ACCESSIBLE TO ALL WHO ARE INTERESTED. THEREFORE, THIS VOLUME BASED UPON THE NATIONAL SIGMA XI LECTURES DELIVERED IN 1937-38 HAS SPECIAL SIGNIFICANCE, SINCE NO OTHER PUBLICATION HAS HAD ACCESS TO THIS MATERIAL. THE BOOK HAS NOT BEEN WRITTEN DOWN TO A POPULAR LEVEL IN AN ENDEAVOR TO ATTRACT THOSE WHO DO NOT HAVE A GENERAL KNOWLEDGE OF MODERN SCIENTIFIC ENDEAVOR, BUT NEVERTHELESS, WHILE MAINTAINING A HIGH DEGREE OF SCHOLARSHIP, THE CHAPTERS ARE INTERESTINGLY WRITTEN AND PROFUSELY ILLUSTRATED WITH STRIKING AND EXTRAORDINARILY VALUABLE PHOTOGRAPHS. HERE ARE THE "MEN AND MACHINES" WHO HAVE MADE IMPORTANT ADVANCES INTO UNMAPPED AREAS, WHO ARE IN THE FOREFRONT OF SCIENTIFIC RESEARCH TODAY.

CONTENTS

Foreword—HARLOW SHAPLEY

Atoms, New and Old—E. O. LAWRENCE, University of California.

The Separation of Isotopes and Their Use in Chemistry and Biology—H. C. UREY, Columbia University.

Recent Advances in the Study of Viruses—W. M. STANLEY, Rockefeller Institute.

New Views in Virus Disease Research—L. O. KUNKEL, Rockefeller Institute.

Vitamins and Hormones—K. E. MASON, Vanderbilt University.

The General Rôle of Thiamin (Vitamin B) in Living Things—R. R. WILLIAMS, Bell Telephone Laboratories.

Hormones in Reproduction—EDGAR ALLEN, Yale University.

Chromosomes in Relation to Heredity—T. S. PAINTER, University of Texas.

Electrical Potentials of the Human Brain—E. N. HARVEY, Princeton University.

Animal Metabolism from the Mouse to Elephant—F. G. BENEDICT, Carnegie Nutrition Laboratory.

THIS VALUABLE ADDITION TO MODERN SCIENTIFIC LITERATURE IS AVAILABLE TO ALL SUBSCRIBERS TO THE RESEARCH FUNDS OF SIGMA XI IN THE SUM OF $4 OR MORE. CONTRIBUTIONS AND ORDERS SHOULD BE SENT TO THE NATIONAL SECRETARY.

REPORT OF THE PRESIDENT FOR 1938

The Society of the Sigma Xi increases in importance and influence with each passing year. Noteworthy events for 1938 follow:

1. NEW CHAPTERS.

Following the action of the 38th Convention, four chapters have been installed during the year:

Rice Institute, March 23.
Massachusetts State College, April 14.
Wellesley College, May 13.
University of Florida, October 28.

This 39th Convention will be asked to take action on petitions for charters for chapters from the University of West Virginia and the University of Alabama. The petitions were circulated among the chapters on November 1.

The Executive Committee has before it preliminary information regarding the resources and equipment and research output of seven institutions from which may come sometime in the future formal petitions for charters for chapters.

The total number of chapters is now seventy-six, with a constituency (members and associates) of approximately 17,000.

At present, in accordance with the action of the 1929 Convention, members and associates are selected from limited fields of science as follows: Mathematics, Physics, Chemistry, Astronomy, Science of the Earth, Biology in its various branches, including Psychology, Anthropology, Medicine in its various branches, Engineering in its various branches.

Following that action of the Convention, and in reply to questions about eligibility submitted by chapters, the Executive Committee voted in 1930 that "in case any chapter is in doubt regarding the eligibility of investigators in other fields, before election takes place, the chapters should ascertain and be guided by the opinion of the Executive Committee or of some of the officers authorized by the Executive Committee to act for it in such matters."

2. NEW CLUBS.

The 37th Convention by constitutional amendment formally recognized Sigma Xi clubs and brought them into official association with the national organization. A Sigma Xi club is composed of individuals who are already members or associates of the Society. It is expected to hold at least two meetings each academic year and to make annual reports of its activities to the national secretary. Clubs are entitled to a delegation of three of its membership at annual conventions, and club delegates have the privilege of the floor at conventions, may participate in the discussion of any item of

business, and vote on questions specifically affecting the alumni of the Society.

During 1938 four clubs have been added—Beloit College, Alabama Polytechnic Institute, Emory University, and North Carolina State College. There are now thirty-seven clubs. The demands on the secretary's office do not permit at present the maintenance of enrollment lists of club constituents, such as we have for chapters, but obviously that must soon come, since clubs are an officially recognized and important part of the national organization. Some future convention will also doubtless wish to consider the matter of including club membership in the annual assessment for the Society's expenses levied by the Convention.

3. THE SIGMA XI LECTURE SERIES.

In 1937 the Society inaugurated a series of five lectures by distinguished investigators to be given before chapters and clubs. Traveling expenses of the lecturers were met by the Society, and the chapter or club engaging them was responsible for an honorarium of $50 for each lecture and for the local entertainment of the lecturer. The Society sponsored a similar series in 1938, and arrangements have been made for a 1939 group. The lecturers and topics for the three series follow:

1937

Edgar Allen, Yale University—"Internal Secretions in Reproduction."
L. O. Kunkel, Rockefeller Institute—"New Views in Virus Disease Research."
E. O. Lawrence, University of California—"Atoms, New and Old."
T. S. Painter, University of Texas—"Recent Developments in Our Knowledge of Chromosome Structure and Their Bearing on Genetics."
H. C. Urey, Columbia University—"The Application of Physical and Chemical Methods to the Problem of the Separation of Isotopes."

1938

F. G. Benedict, Nutrition Laboratory, Boston—"Animal Metabolism—from Mouse to Elephant."
E. N. Harvey, Princeton University—"Electrical Potentials of the Human Brain."
K. E. Mason, Vanderbilt University—"Vitamins and Hormones."
W. M. Stanley, Rockefeller Institute—"Studies on Virus Proteins."
R. R. Williams, Bell Telephone Laboratories—"Vitamins B_1 and Cell Metabolism."

1939

Carl D. Anderson, California Institute of Technology—"Cosmic Rays and New Elementary Particles of Matter."

Louisiana State University
Tulane University
Duke University
Brown University
University of Maine
University of Vermont
Beloit College
University of Cincinnati
University of Michigan
Ohio State University
College of Medicine, University of Illinois
Northwestern University
Iowa State College
University of Nebraska

Jerome C. Hunsaker, Massachusetts Institute of Technology—"Recent Advances in Aeronautics."

Swarthmore College
Bucknell University
Cornell University
University of Washington
State College of Washington
University of Arizona
Oklahoma A. and M. College
University of Alabama

Alfred C. Lane, Emeritus, Tufts College—"Does Mother Show Her Age?"

University of Texas
Rice Institute
University of Idaho
University of Washington
University of Wyoming
University of North Dakota

Howard P. Robertson, Princeton University—"The Expanding Universe."

Louisiana State University
University of New Mexico
Stanford University
University of Washington
Swarthmore College

Lewis J. Stadler, University of Missouri—"The Experimental Alteration of Heredity."

Oregon State College
Utah State Agricultural College
University of Nebraska
State University of Iowa
College of Medicine, University of Illinois
University of North Carolina

In 1937 the five lecturers gave a total of twenty-seven lectures; in 1938, thirty-one lectures; for the coming year thirty-nine lectures have been engaged.

A part of this plan of Sigma Xi lectures includes the publication of the lectures in permanent form. The 1937 and 1938 series will shortly be published in one volume by the Yale University Press under the title "Science in Progress," with a foreword by Professor Harlow Shapley. Date of publication is set for next March.

4. The Sigma Xi Grants-in-aid.

This activity of the Society was begun in 1920, when the alumni (that is, those members and associates not connected with chapters) contributed $3,100 for distribution as grants-in-aid of research. The largest amount distributed in any one year was $3,600 in 1927. The sum available this year was $2,981.50, and was contributed by approximately 900 members and associates. Individual gifts vary from ten cents to $100. This year there were two subscriptions of $100; five of $25; five of $20; two of $15; and many of $10.

To the contributions for this year the Executive Committee added $600 from the General Funds of the Society. The total sum awarded for 1938-39 is $3,425.

The first awards were made by a subcommittee of the Executive Committee and the original policy was to use the available funds in the form of a fellowship to one or two individuals. Since 1924 grants have been awarded by a special committee, at present consisting of Dr. W. R. Whitney, Vice-President of the General Electric Company in charge of Research; Professor Gary N. Calkins of Columbia University; and Professor Harlow Shapley of Harvard University.

The awards for 1938-39 are as follows:

Clifford Ackermann Angerer, University of Pennsylvania, $200. For continuation of studies on protoplasm of single cells of the effects of various stimulating agents, particularly electric current, on the viscosity and morphological changes induced at the time of and during recovery from stimulation.

Clair A. Brown, Louisiana State University, $100. For continuation of studies on the flora of the isolated prairies in Louisiana.

Dwight Clark Carpenter, New York State Experiment Station, $200, on condition that he finds it possible to secure an additional $100 from some other source. For work on the effect of neutral salts on amino-acids and proteins.

Donald Paul Costello, University of North Carolina, $100. For studies on the Genus Polychoerus Mark.

Malcolm Dole, Northwestern University, $200. For study of the influence of negative ions on the potentials of the glass electrode in the alkaline range, not only to discover the practical limits of the glass electrode, but also to obtain data which will lead to a better understanding of the instrument.

Frank Kelly Edmondson, Indiana University, $100. For investigation of absorption of starlight by the dark nebula in Taurus by means of star counts and measures

of color on plates made with our 24-inch Schwarzschild reflector. Work to be carried on in collaboration with Dr. S. W. McCuskey of the Case School.

Betty Nims Erickson, Children's Fund of Michigan, $250. For study of hemorrhagic diseases in infants and children.

E. A. Fath, Carleton College, $175. For work on stellar variations measured photoelectrically at the Lick Observatory.

Rachel E. Hoffstadt, University of Washington, $250. For continuation of study of Myxamatosis of rabbits, and Fibroma OA and IO on developing embryo.

Ralph J. Kamenoff, City College of New York, $200. For work on selective inbreeding to study the genes which modify the expression of the flexed-tail gene; further study of the anemia of the flexed-tailed mice through an analysis of embryonic hemapoiesis.

Norton Adams Kent, Boston University, $300. For work on the development of an atomic beam of hydrogen as a source to be used in studying the fine structure of the lines in the atomic spectra of hydrogen and deuterium.

George Wallace Kidder, Brown University, $300. For continuation of investigation of the factors influencing growth and reproduction, using *Colpoda steini* as the experimental animal.

Harold Kirby, Jr., University of California, $200. For studies of protozoa of termites.

Konrad Bates Krauskopf, Stanford University, $50. For study of origin and relations of old volcanic rocks in northern Washington believed to contain an unusually large amount of sodium.

Oliver A. Leonard, Texas A. and M. College, $100. For study of the effect of temperature and other factors on sugar transformations.

Elsie Murray, Cornell Optical Laboratory, $300. For standardization of technique for recording cases of aberrant color vision.

Alfred Perlmutter, New York State Biological Survey, $150. For analysis of the geographical variation in characters shown by a number of ocean and bay fishes of the Atlantic coast of North America, with special reference to the correlation between the variations and the temperature, salinity, and other features of the environment.

W. P. Spencer, Wooster College, $250. For work on comparative biology of Drosophila species.

The expense of circularizing the alumni in the interest of this research fund was for seven years (1921-28) met out of the contributions. In 1929 the Convention authorized the Executive Committee to defray this expense out of the general funds of the Society so that every dollar contributed could be used to further the object of the fund, the promotion and support of research.

5. The General Policy of the Society.

The first article of our National Constitution declares the object of the Society of the Sigma Xi to be "to encourage original investigation in science pure and applied."

In pursuance of that object the activities of the Society have been multiplied in number and widened in scope during the fifty years of its life. In the first quarter century of the Society its activities were limited to local chapter meetings, election of students to membership, and the publication of a quarterly journal which for the most part confined its contents to convention proceedings, announcement of Executive Commitee actions, and reports from the chapters. In its second quarter of a century, these original activities of the Society were continued and strengthened, and new and important movements broadened the sphere of the work and influence of Sigma Xi. The subscription list of the Quarterly has now reached the impressive number of approximately 17,000, and each issue contains timely articles by distinguished scientists, representing all fields of science recognized by our organization. We now have an endowment fund of approximately $40,000. Annual grants-in-aid of research are made. From time to time Sigma Xi awards prizes for

research in progress and accomplished. For seventeen years our Society has had charge of the second of the general meetings of the December Convention of the A. A. A. S., and for three years has sponsored a series of lectures before chapters and clubs all over the United States.

In view of those greatly multiplied activities, and of the constantly increasing widening of the areas of the Society's influence in educational and research institutions, it became apparent to the national officers that the situation required a "Committee on Policy" to coordinate present activities, and to shape a policy for the future. That committee is made up as follows: Professor Gortner, chairman; Professors Parker and Baitsell, representing past and present elected officers; Professors Leuschner and Miller, representing the Executive Committee; Mr. Davies and Mr. Norton, representing the Alumni.

This committee on policy has made some definite recommendations which the Executive Committee has under consideration for report to the convention in the near future. Some of them are as follows:

a. *The Officers of the National Society.* The 40th Convention of the Society will be called upon to select a president, secretary and treasurer, and a member of the Executive Committee.

b. *Use of Income from Invested Funds in Promotion of Research.* The question involved here is the form that the use of such income shall take. The Executive Committee is clear in its opinion that the income shall be definitely used in and for research, but has not reached decision as to the exact form such use shall take, whether of medals, money prizes, grants-in-aid, etc.

c. *The* QUARTERLY. The time has come when the importance and value of the Society's QUARTERLY require an Editorial Board to select and supervise the contents of the journal. The president appointed a special committee, with Dean Richtmyer of Cornell as chairman, to take this matter under advisement for report at this time. The report was presented at the meeting of the Executive Committee prior to this convention. Definite action will probably be taken in the spring meeting, and recommendations made to the 40th Convention.

6. SUGGESTIONS FROM CHAPTERS AND CLUBS.

The Executive Committee urges chapters and clubs to discuss and study its conduct of the Society's business, all the activities of Sigma Xi in the promotion of research, changes and improvements in policy, progress and expansion of the Society's work in all fields of science, and to make recommendations. You are positively and sincerely assured that every suggestion you make will be welcome, and be given careful and grateful consideration.

GEORGE A. BAITSELL, *President.*

December, 1938.

REPORT OF THE SECRETARY FOR 1938

The work of the secretary's office grows apace. You would all be interested to see it—the office, I mean. I wish you might. It consists of three small rooms of the Butterfield Chemical Laboratory of Union College and a part of a larger fourth room. The furnishings are certainly not handsome—hardly dignified enough or worthy for the headquarters of such a large and important and prominent organization as the Society of the Sigma Xi. You would probably say (and be not far from correct) that it was all of a clutter or mess. Shelves hold back issues of the QUARTERLY dating from 1912, supplies of stationery, order blanks and price lists of Sigma Xi insignia, stock of blank filing cards for records of new members and associates, blank diplomas for members and associates, and stationery for the officers of the Society. One large cabinet, with a capacity of 20,000 stencils, holds the stencils of the chapter enrollments arranged geographically; two, with a capacity of 20,000 stencils each, hold stencils for members and associates at present not connected with chapters, also arranged geographically. One cabinet contains the chapter files, that is, the record cards of all members and associates elected into the Society since its origin in 1886—now over 40,000 cards—arranged according to chapter. Two other cabinets contain a set of record cards of members and associates, arranged alphabetically. Stacked on the floors of the various rooms is the supply of about 60,000 wrappers for the QUARTERLY (less than a year's supply) and the store of the *Half Century Record and History* published two years ago. The power-driven addressograph machine for addressing QUARTERLY wrappers and envelopes for our annual circularizing of the constituency occupies some space, and of course the clerks' desks and typewriters. That is what the mere mechanics of the work of the office of the National Secretary of Sigma Xi has come to in the last twenty years or more.

Now as to some specific items in the year's activities:

1. MAINTENANCE OF RECORDS.

   a. *Proceedings of the annual Conventions and meetings of the Executive Committee.* This is fairly simple—that is, does not take much time or involve much clerical work. The Proceedings and the Minutes are made up within a few hours after adjournment, are submitted to the members of the Executive Committee immediately for correction, and printed in the QUARTERLY. The agenda for both can be formulated at a day's notice, since all matters to come before each group are filed daily in the secretary's office.

   b. *Individual Records of Members and Associates.* Here we are absolutely dependent upon chapter secretaries, who are asked to send in to headquarters record cards for newly elected members and associates immediately following initiation. There is considerable labor connected with this. You can see why it should be so. There are now seventy-

six chapters. Elections take place usually between January and May. When the cards are received and before they can be filed in the chapter files, a duplicate card must be typed for the alphabetical file, and a stencil made for the geographical file (that is the addressograph list). We are now electing between 1,500 and 2,000 members and associates each year. That gives you an idea of the time and work involved in that part of the routine of the secretary's office.

c. QUARTERLY *Mailing List.* Every member and associate reported to us as enrolled in a chapter, and every new member and associate, are entitled to receive the QUARTERLY for one year following the date of the receipt of the report of their connection with the Society. This means constant revision of that address list of now about 17,000 names, and it involves a great deal of time. We are never up to date with the work, because we do not have adequate clerical service in that work—one-half of one clerk's time. But we are constantly at it, and perhaps somes day with increased service we will be up to date with a correct list at all seasons of the year.

In connection with this work of the maintenance of records, we are still receiving complaints regarding omissions of names from our *Semi-Centennial Record and History*—not many, but they continue to come in. In every case thus far, the secretary feels virtuous in reporting, the omission has been due to the fact that the name and record of the complainant have not been in the chapter files. Chapter secretaries have responded at once with the proper record, when the cases have been reported to them, and we complete the record for each individual. That does not bring the individual's name into the *Semi-Centennial Record and History*, but it assuredly will appear in its proper place when we publish the next History twenty-five years hence.

Chapter secretaries have cooperated with headquarters pretty well during 1938 in submitting promptly the names and records of new members. Of our seventy-six chapters, reports of 1938 elections have been received to date from fifty-five.

2. THE QUARTERLY.

Of course the editorship of such an important journal as the SIGMA XI QUARTERLY should no longer be a one-man responsibility, and least of all the national secretary's, whose available time and thought and energy are absorbed with the duties of administration of the affairs of a large and influential Society. The QUARTERLY is widely read—approximately 17,000 was the number printed of the December issue—and it reaches scientific workers in all the fields of science and technology represented in the Society—Mathematics, Physics, Chemistry, Astronomy, Sciences of the Earth, Biology in its various branches, including Psychology, Anthropology, Medicine in its various branches, Engineering in its various branches.

Published articles in the QUARTERLY cover topics in all those fields. No one man can properly judge the publication and research value of papers in

so many different sciences, least of all the present editor. The time has come when the SIGMA XI QUARTERLY should be in the hands of an editorial board, probably of nine members representing the nine fields of science in which the Society supports and promotes research. The report of the special committee on the QUARTERL., of which Dean Richtmyer of Cornell is chairman, must be received with gratitude and pondered thoughtfully.

The general excellence of the articles published in the four issues for 1938 is not all due to powers of discrimination of the present editor. He has no such powers. It is due entirely to the fact that with few exceptions the published papers were addresses given before chapters—and their unusual value and readability are a convincing comment on the influence and quality of chapter activities. The few invitation articles were in fields with which the editor is acquainted, and by individuals whose work and ability he feels competent to evaluate properly.

Here are the titles of articles published in 1938:

PSYCHOLOGY:
The Wisdom of the Mind—PROFESSOR JOHN M. FLETCHER, Tulane.
Inheritance of Emotionality—DR. CALVIN S. HALL, Western Reserve.
Extra-Sensory Perception—PROFESSOR J. B. RHINE, Duke.

BOTANY:
Influences That Affect Transpiration From Plant Leaves—PROFESSOR BURTON E. LIVINGSTON, Johns Hopkins.

FOODS:
Fads, Fancies and Fallacies in Adult Diets—DR. RUSSELL M. WILDER, The Mayo Clinic.
The Feeding of the Child—DR. CHESTER A. STEWART, Minnesota.

CHEMISTRY:
The Setting of a Gel—Physiological Implications—PROFESSOR CHARLES B. HURD, Union.
The Adrenal Cortex and Carbohydrate Metabolism—DR. C. N. H. LONG, Yale University School of Medicine.
Chemical Stimulation in Animals—PROFESSOR WILLIAM H. COLE, Rutgers.

ASTRONOMY:
The Invisible Universe—PROFESSOR PETER VAN DE KAMP, Swarthmore.

GENERAL:
The Chief Concern of the Scientist—ALBERT EINSTEIN.
Student, What Next?—DR. A. GRAEME MITCHELL, Cincinnati.
Sigma Xi Initiates—PROFESSOR W. C. GEORGE, North Carolina.
Science and Research in Modern Civilization—DR. M. L. WILSON, Undersecretary of Agriculture.

In prospect for future issues of the QUARTERLY:

Dental Research—DR. J. L. T. APPLETON, Pennsylvania.
The Chemistry of the Tubercle Bacillus and Related Acid-Fast Bacteria—PROFESSOR R. J. ANDERSON, Yale.
Nutrition and Human Welfare—PROFESSOR L. A. MAYNARD, Cornell.
Drug Addiction Problems—DR. M. H. SEEVERS, Wisconsin.
Newfoundland; Geology and People—PROFESSOR W. H. TWENHOFEL, Wisconsin.

3. THE SIGMA XI INSIGNIA.

Following many months of correspondence and direct negotiation, the secretary is glad to report, you will be glad to hear, and prospective new members and associates will be glad to know, that the prices of the different styles and sizes of the Society's emblems will be somewhat reduced beginning with the first week of January, as follows:

	Present Prices	Prices after January 1
No. 1—Octagonal solid type:		
Yellow gold	$ 8.00	$ 6.25
White gold	10.00	7.75
No. 2—Monogram, usual size:		
Yellow gold	$ 8.75	$ 6.25
White gold	10.75	7.75
No. 3—Monogram, small size:		
Yellow gold	$ 6.50	$ 5.00
White gold	8.25	6.00
No. 4—Associate:		
Yellow gold	$ 4.00	$ 2.50
White gold	5.00	3.00
Conversion of Associate to Member:		
Yellow gold	$ 6.50	$ 4.75
White gold	7.25	4.75

(Pin joint and safety catch on any style 50 cents additional.)

The quality of the content and workmanship will be of the same high standard as heretofore. By definite contract with the official jeweler these prices will remain fixed for two years, all orders will be shipped within five days after receipts, and rush orders within twenty-four hours; new illustrated price lists and order blanks will be issued at once, and chapter secretaries will be asked to discard whatever stock of those they may now have on hand.

The secretary cannot close his annual report without an expression of his deep appreciation of the great patience with his shortcomings and the helpful cooperation in the work of the office which the chapter officers and others who have been in correspondence with him have exhibited throughout the year. In an organization as large as ours, and with the many different kinds of demands on the secretary's office, mistakes and errors are inevitable. We want to know about them. We apologize for them all, assure you of our constant and genuine effort to avoid them, and are grateful for your generous forbearance.

EDWARD ELLERY, *National Secretary.*

December 28, 1938.

REPORT OF THE TREASURER FOR 1938

TOTAL RECEIPTS AND DISBURSEMENTS FROM ALL SOURCES AND FUNDS

(The 1938 assessment of all chapters, except McGill University which paid just after the end of the fiscal year, are paid)

RECEIPTS

Cash on hand, December 31, 1937	$ 2,976.68	
Chapter assessments for 1938	8,068.00	
Chapter assessments for 1937, arrears	152.25	
Chapter assessments for 1939, advance	53.25	
Initiation fees for 1938	2,589.00	
Initiation fees for 1937, arrears	282.00	
Installation fees	200.00	
Interest on investments	1,206.74	
Sale of insignia in 1938	900.00	
Sale of insignia in 1937	1,050.00	
Lecturers' stipends	1,450.00	
Lecturers' expenses	8.25	
Alumni contributions for research	3,015.50	
Endowment Fund	232.17	
Overpayments	53.15	
		$22,236.99

DISBURSEMENTS

Secretary's office (total, $4,820.25)		
assistants	$ 2,632.00	
office supplies, stamps, etc.	388.25	
secretary's stipend	1,800.00	
Treasurer's office (total, $200.25)		
assistant	150.00	
postage, supplies, etc.	18.95	
auditing 1938 books	10.00	
custodian account	8.80	
treasurer's bond	12.50	
Officers' traveling expenses	1,119.27	
QUARTERLY (4 issues)	2,735.10	
Circularization of alumni for research contributions	579.63	
Engrossing charters	159.70	
Lecturers' stipends	1,450.00	
Lecturers' expenses	1,386.62	
Grants-in-aid of research, 1938-39	2,400.00	
Return of overpayments	53.15	
		$14,903.97
Cash on hand, December 31, 1938		7,333.02
		$22,236.99

February 9, 1939.

GEORGE B. PEGRAM, *Treasurer.*

ALUMNI FUND FOR RESEARCH ACCOUNT

RECEIPTS

Cash on hand, December 31, 1937	$ 000.00	
Appropriations from Society funds to cancel indebtedness of Alumni Fund (Ex. Com. Minutes, April, 1938)	2,542.63	
Receipts from contributions by Alumni members (received through Secretary's office)	3,015.50	
Interest on Semi-Centennial Fund allocated to Alumni Fund (Ex. Com. Minutes, April, 1938)	600.00	
		$ 6,158.13

DISBURSEMENTS

Debt to the Society paid by appropriation from the Society		$ 2,542.63	
Payments on Grants for Research (1938-39):			
Malcolm Dole	$ 200.00		
Norton A. Kent	300.00		
D. P. Costello	100.00		
R. J. Kamenoff	200.00		
Harold Kirby, Jr.	200.00		
Elsie Murray	300.00		
O. A. Leonard	100.00		
R. G. Hoffstadt	250.00		
F. K. Edmondson	100.00		
B. N. Erikson	250.00		
G. W. Kidder	200.00		
Clifford A. Angerer	200.00		
		2,400.00	
Cash on hand,* December 31, 1938		1,215.50	
			$ 6,158.13

* This is included in total cash on hand, page 1 of this report.

SEMI-CENTENNIAL FUND

(Executive Committee Minutes, April 27, 1938—"It was voted:

a. That from the funds of the Society an appropriation of $2,542.63 be made to the Alumni Fund account to cancel the indebtedness of the Alumni Fund to the Society.

b. That from the funds of the Society an appropriation of $2,973.76 be made as a contribution to the Semi-Centennial Fund, now $12,026.24, to increase that fund to $15,000.

c. That the Semi-Centennial Fund of $15,000 be set up as a separate fund in the accounts of the Society, represented by $15,000 market value of whatever securities may be owned by the Society; that no part of the principal of this Semi-Centennial Fund shall be expended; that the Society shall undertake at all times to keep its investments at a market value of at least $20,000 in order to protect this Semi-Centennial Fund.

b. That the Society shall until further action apportion interest to the Semi-Centennial Fund at the rate of 4 percent annually.

e. That in accordance with assurances given in soliciting subscriptions to this fund, the interest on the Semi-Centennial Fund shall be used only for direct aid to research.)"

PRINCIPAL ACCOUNT

Net amount from contributions, January 1, 1938	$11,865.57	
Additional contributions received to April 12, 1938	160.67	
Appropriated by the Ex. Com. from funds of the Society, April 27, 1938	2,973.76	
		$15,000.00
The Semi-Centennial Fund, in accordance with resolutions of the Executive Committee, now represented by $15,000 of the market value of the securities owned by the Society, which securities now have a market value above $20,000		$15,000.00

INTEREST ACCOUNT

In accordance with resolution *d.* above interest on the $15,000 Semi-Centennial Fund was apportioned at the rate of 4 percent	$ 600.00
In accordance with resolution *e.* above interest apportioned to the Semi-Centennial Fund has been used for direct aid to research through the Alumni Fund for Research	600.00
	000.00

February 9, 1939. GEORGE B. PEGRAM, *Treasurer.*

INVESTMENT ACCOUNT

(Securities carried at cost)

All companies continue to pay interest on their bonds except the St. Louis and San Francisco Railway, which is in receivership, and the Erie Railroad Company.

$1,000 Amer. Tel. & Tel. Co. 5½% (1943) bond at	$ 991.94
$1,000 St. Louis & San Francisco Railway 4% (1950) bond (certificate of deposit)	796.35
$1,000 Baltimore & Ohio Railway 5% (2000) bond at	955.00
$1,000 Philadelphia Company 5% (1967) bond at	979.50
$1,000 Erie Railroad Company 5% (1967) bond at	947.00
$1,000 Southern Railway Company 6% (1956) bond at	1,152.00
$1,000 Philadelphia Company 5% (1967) bond at	997.00
$1,000 Canadian Pacific 5% (1954) bond at	1,010.00
$1,000 U. S. Treasury 4% (1954) bond at	999.06
$1,000 U. S. Treasury 3% (1955) bond at	942.50
$1,000 U. S. Treasury 3% (1955) bond at	942.50
$1,000 U. S. Treasury 3% (1955) bond at	942.50
$1,000 U. S. Treasury 2⅛% (1939) bond at	1,019.37½

\$1,000 U. S. Treasury 2⅛% (1939) bond at	1,019.37½
\$1,000 U. S. Treasury 2⅛% (1939) bond at	1,019.37½
\$1,000 U. S. Treasury 2⅛% (1939) bond at	1,019.37½
\$1,000 U. S. Treasury 2⅛% (1939) bond at	1,019.37½
\$1,000 U. S. Treasury 2⅛% (1939) bond at	1,019.37½
\$200 New York City 4% (1938) bond redeemed at	200.00
\$200 New York City 4% (1939) bond at	198.50
\$200 New York City 4% (1940) bond at	198.50
\$200 New York City 4% (1941) bond at	198.50
\$200 New York City 4% (1942) bond at	198.50
\$200 New York City 4% (1943) bond at	198.50
\$1,000 Southern California Edison Co. 3¼% (1960) bond at	1,065.00
\$1,000 Southern California Edison Co. 3¼% (1960) bond at	1,065.00
\$1,000 Consumers Power Co. 3½% (1963) bond at	1,057.50
\$1,000 Consumers Power Co. 3½% (1965) bond at	1,057.50
\$1,000 Edison Elec. & Illum. Co. 3½% (1965) bond at	1,071.25
\$1,000 Edison Elec. & Illum. Co. 3½% (1965) bond at	1,071.25
\$1,000 General Motors Acceptance Co. 3% (1946) bond at	1,027.50
\$1,000 General Motors Acceptance Co. 3% (1946) bond at	1,027.50
\$1,000 General Motors Acceptance Co. 3% (1946) bond at	1,027.50
\$1,000 Consolidated Edison Co. 3¼% (1946) bond at	1,047.50
\$1,000 Consolidated Edison Co. 3¼% (1946) bond at	1,047.50
\$1,000 Consolidated Edison Co. 3¼% (1946) bond at	1,047.50
\$1,000 U. S. Treasury 3⅛% (1946-49) bond at	1,069.06¼
\$1,000 U. S. Treasury 3⅛% (1946-49) bond at	1,069.06¼
\$1,000 U. S. Treasury 3⅛% (1946-49) bond at	1,069.06¼
\$1,000 Southern Pacific Co. 4½% (1969) bond at	905.75
\$1,000 Southern Pacific Co. 4½% (1969) bond at	907.00
	\$36,596.54

December 31, 1938. GEORGE B. PEGRAM, *Treasurer.*

AUDITORS' STATEMENT

We have audited the accounts of the Treasurer of the Sigma Xi Society for the year ending December 31, 1938, and have found that all income as contained in the records was duly accounted for and that disbursements were supported by proper vouchers. The securities listed above were verified by certificates from the Custodian, namely, The Corn Exchange Bank Trust Company, except for the St. Louis and San Francisco Railway Bond for which the Treasurer holds a Certificate of Deposit. We certify that the foregoing statements of assets, income and expenses fairly present the operations for the year and the financial position of the Society as of December 31, 1938.

J. T. FINNERAN,
FRANK X. FARR,
Auditors.

February 9, 1939.

CHAPTER OFFICERS

List Furnished by the Secretaries of the Chapters

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	S. Brody	H. E. French	L. J. Wells	J. Q. Adams
	C. L. Eckel	F. G. Ebaugh	Hugo Rodeck	N. F. Witt
		F. G. Walz		
...ern	A. Weil	C. H. Behre	M. Dole	C. D. Turner
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...t. of ...ogy	P. W. Merrill	H. Bateman	F. C. Lindvall	H. J. Fraser
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	G. E. Cullen	F. O'Flaherty	S. B. Arenson	S. B. Arenson
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	Lila Sands	D. M. Crooks	F. E. Roach	F. E. Roach
	T. E. Butterfield	H. A. Neville	P. B. Carwile	D. M. Fraser
	C. G. Eichlin	C. E. White	R. Bamford	R. Bamford
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...Inst. of ...logy	J. B. Rosenbach	C. R. Fettke	H. C. Howard	R. T. Gabler
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	A. C. Chandler		G. H. Richter	J. H. Pound
...etts State	C. R. Fellers	W. S. Ritchie	H. Van Roekel	C. P. Alexander
	Ruth Johnstin	M. J. Zigler	H. W. Dodson	H. W. Kaan
	P. H. Senn	C. F. Byers	R. B. Becker	J. E. Hawkins

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Beloit College	C. Welty		N. Bennington	N. Benning
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